Journal

WATER POLLUTION CONTROL FEDERATION

Special Features

Radioisotope Test for Coliforms—Levin et al.

Legal Responsibilities of Operators—Samson

Cellulose in Activated Sludge—Hurwitz et al.

Tastes and Odors—Baker

Steel Mill Sludge—Hoak

Orlon Wastes—Taylor et al.

Deeds and Data

OCTOBER 1961

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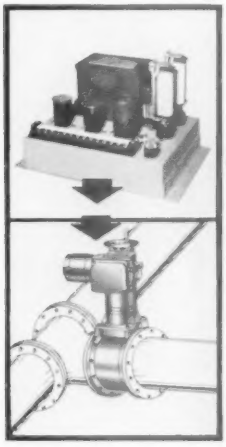

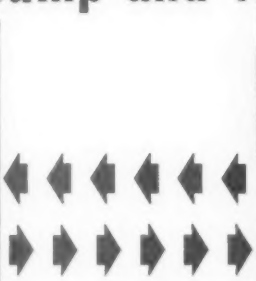

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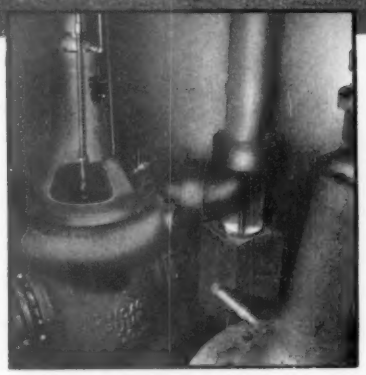

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JOURNAL of the WATER POLLUTION CONTROL FEDERATION

Volume 33 | October 1961 | Number 10

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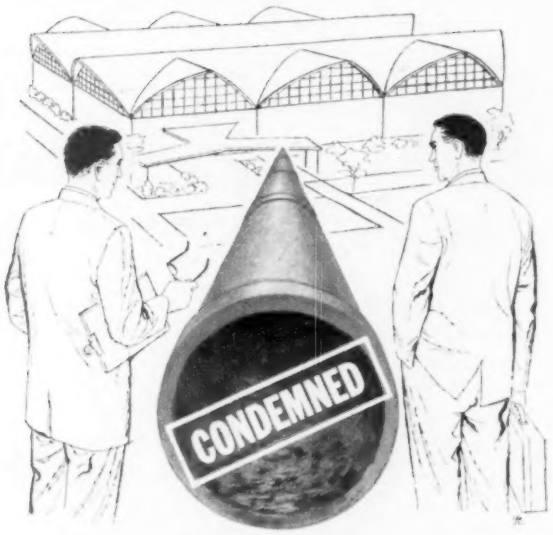

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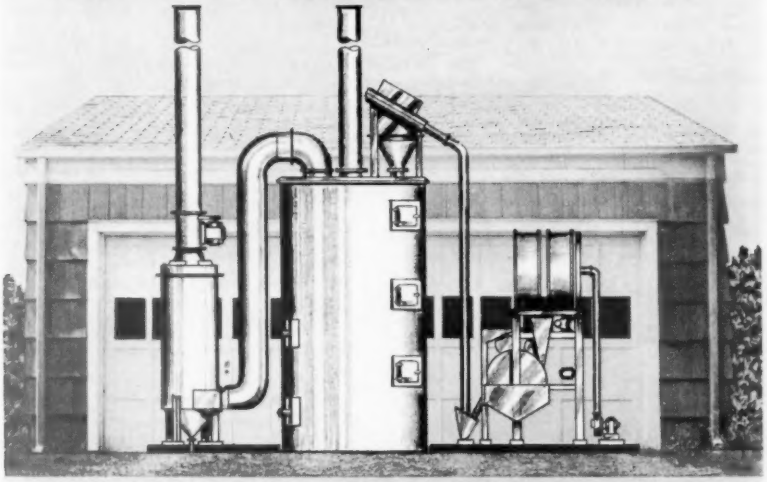

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QUALITY K-S EQUIPMENT

COILFILTER OPERATING DATA Month July

City of Beatrice, Nebraska Equiv. Pop. 12848 (Sus. Solids)

Chemicals vs Dry Wt. Solids Pounds Used		Percent Used		FILTER CAKE % Moisture	Yield lbs./sq. ft./hour	pH sludge before chem	pH sludge after chem
Lime	$FeCl_3$	CaO	$FeCl_3$				
850	89	7.1	1.2	76	8.4	6.4	11.8
735	120	6.8	1.1	72	10.7	6.8	12.0
420	64	5.5	0.8	76	10.8	6.8	11.8
490	67	6.2	0.8	76	10.4	6.4	12.0
550	58	6.7	1.1	74	8.2	6.2	11.8
400	42	7.0	1.5	76	7.9	7.0	11.8
700	64	7.4	0.9	75	9.4	6.8	11.8
600	59	7.2	1.2	74	8.2	6.6	11.8
500	47	6.1	0.9	72	11.2	6.8	12.0
650	64	6.7	0.9	76	9.5	6.8	12.0
650	61	7.7	1.3	79	8.3	6.6	11.8
600	67	7.0	1.1	76	8.4	6.8	11.6
7145	802			75.1	9.2	6.66	11.85
595.4	66.08	6.71	1.06				
3.57 (Tons)							

MONTH'S AVERAGE

**Note: PC for Primary Clarifi
HT for Holding Tank
D for Digest

ER DEWATERING COST

Unit Cost	Cost per Month	Cost/ton dry wt	Cost/capita/yr.
12.5¢	100.25	2.86	.093
1.2¢	85.74	3.32	.080
	185.99	6.18	.173

*For Filtration Operation Only

Signed: Wayne Bitting
Title: Water Supt.
Date: 8-8--60

The Beatrice, Nebraska, sludge dewatering report shown here is not unusual; it is representative of the scores of Coilfilter fresh solids dewatering installations throughout the country, as well as the hundreds of other Coilfilters dewatering digested or primary and trickling filter sludges.

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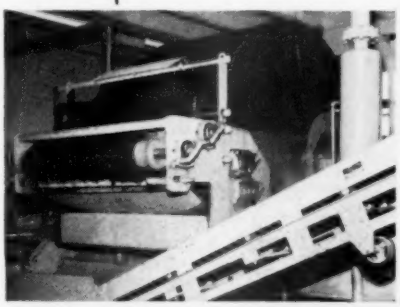

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Association *	*Date*	*Place*
Canada	Oct. 22–25	Sheraton-Mt. Royal, Montreal, Quebec, Canada
Pacific Northwest	Oct. 25–28	Hotel Winthrop, Tacoma, Wash.
Florida	Oct. 29–Nov. 1	Cherry Plaza Hotel, Orlando
New England	Nov. 1–2	Northampton Hotel, Northampton, Mass.
Nebraska	Nov. 8–9	Hotel Lincoln, Lincoln
South Carolina	Nov. 10	Richland County Health Center, Columbia
North Carolina	Nov. 13–15	George Vanderbilt Hotel, Asheville
Indiana	Nov. 15–16	Hotel Washington, Indianapolis
Oklahoma	Nov. 27–Dec. 1	Oklahoma State University, Stillwater
Louisiana	Mar. 14–16, 1962	Louisiana State University, Baton Rouge
Kansas	May 2–4	Lassen Hotel, Wichita
Arizona	May 3–5	Pioneer Hotel, Tucson
Michigan	May 21–23	Park Place Hotel, Traverse City
Central States	June 20–22	Hotel Duluth, Duluth, Minn.

* See preceding left-hand page for full name.

THIRTY-FIFTH ANNUAL MEETING

Water Pollution Control Federation

HOST—Canadian Institute on Sewage and Sanitation
Toronto, Ontario, Canada

Royal York Hotel
October 7–11, 1962

INFILCO completely-mixed activated sludge plants cut B.O.D. removal costs 25-50%

1. Litchfield, Minn. Twin unit plant, each unit 47' dia. Consulting Engineers—Bonestroo, Rosene & Assoc., St. Paul. 2. Thousand Oaks, Calif. Single unit (in foreground), 67' dia. Consulting Engineers—Pomeroy and Associates, Pasadena. 3. Santee, Calif. Single unit, 67' dia. Consulting Engineers—Lawrence, Fogg, Florer & Smith, La Mesa, Calif.

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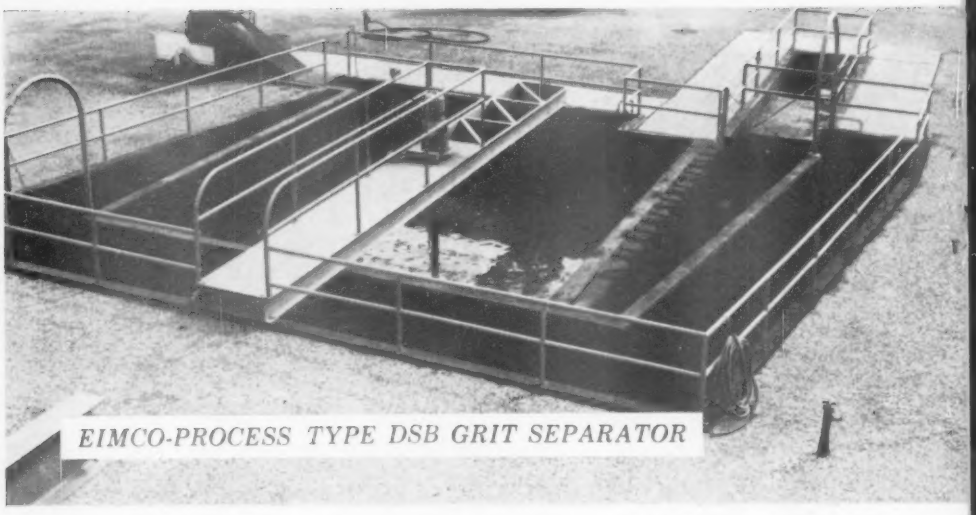
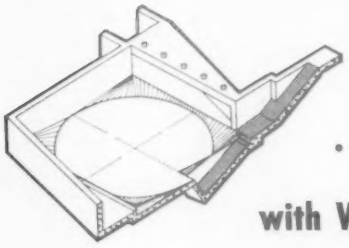
3440 Prudential Plaza, Chicago 1, Illinois

CAST IRON PIPE
THE MARK OF THE 100-YEAR PIPE



EIMCO-PROCESS TYPE DSB GRIT SEPARATOR



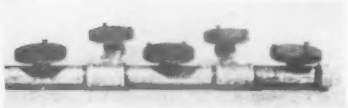
Improved Grit Washing

. . . Better Organics Removals

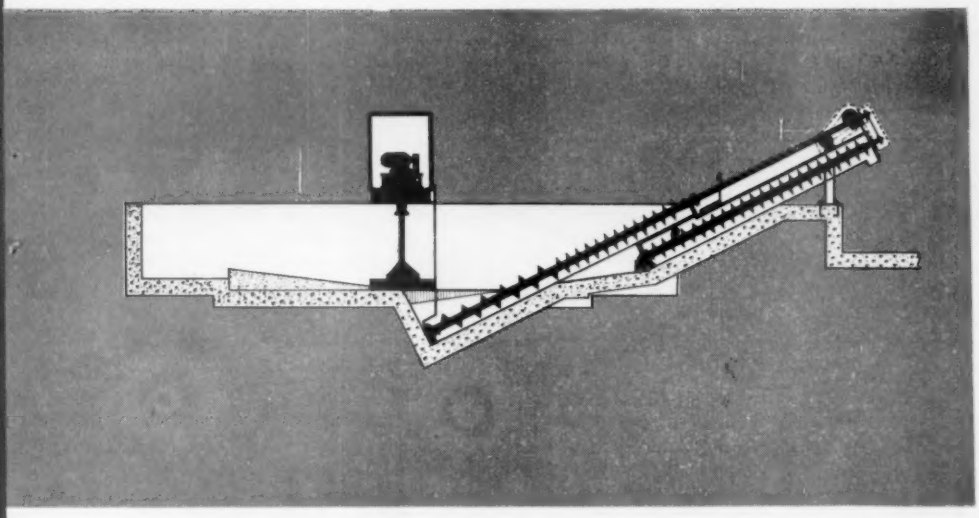
with Washer INSIDE the Collection Tank!

- No dead spaces. Floating putrescibles can't accumulate, with spiral washer on the inside of the collection tank. No scum hosing. Movement of sewage across grit pocket reduces amount of organics that can deposit with the solids to a minimum. No odor or fly nuisance.
- Variable speed drive accommodates wide variations between minimum and maximum flows . . . keeps organics from dropping out with the grit at low flows. Speed of grit collector mechanism is varied inversely with the velocity of the flow in the collection compartment.
- Cleaned, washed grit is elevated sufficiently high above outlet for convenient disposal.

EIMCO-PROCESS NON-CLOG DIFFUSERS



Uniform air flow without clogging. Air diffuser floating top plate settles and seals off air aperture when pressure drops. Built for 1½ to 4-in. pipes Bulletin **PJ-1012.**



Eimco-Process Type DSB Grit Separator, for large flows or deep collection tanks, has two spiral washers in series, the lower discharging into the washer trough of the upper. Grit is retained and scoured in the lower end of the upper screw by interrupted spiral flights for additional removal of organics. Both spirals driven by one drive.

Eimco-Process also builds Type SB Grit Separators, with single screw washer, for small flows or shallow tanks. The Eimco-Process representative in your area will be glad to discuss good housekeeping in grit separation with you and your consulting engineers. Call him or write Eimco's Process Engineers Division, 420 Peninsular Ave., San Mateo, California, U.S.A. for Bulletin PJ-1007.

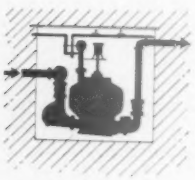
EIMCO

"Advanced Engineering and Quality Craftsmanship Since 1884"

B-788

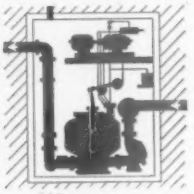
Which sewage lift station is best for your job?

TOPS IN DEPENDABILITY AND SAFETY



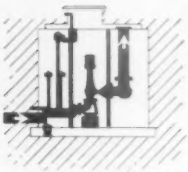
Concrete or steel underground station with Shone® Type S pneumatic ejector, mechanically controlled (warranted 25 years). Remote air supply. Nothing electrical; maintenance free; operates even under water. For municipalities and large subdivisions.

SUPRISINGLY VERSATILE, INEXPENSIVE



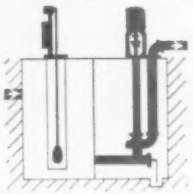
Shone® Type SAC station, underground in concrete vault. Mechanically controlled ejector (warranted 25 years) has its own compressor. Frequently less costly than package stations. Finds use everywhere.

PACKAGE STATION



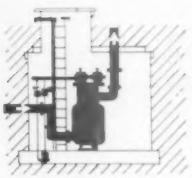
Quality underground station with vertical, short-coupled (Series 6260), dry pit centrifugal pumps. Quality design and equipment give good service life at nominal cost. For small permanent stations, growing areas.

LOW FIRST COST—EASY INSTALLATION



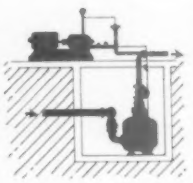
Two-compartment steel basin with centrifugal vertical wet pit pump. Pumps are not submerged; motors protected from flooding. Low first cost; fast installation. For buildings, small growing subdivisions.

ULTIMATE IN PACKAGE DESIGN



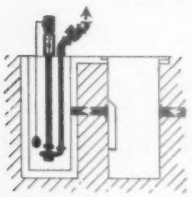
Package underground station with Expelsor® pneumatic ejector, electrode controlled. Sanitary and dependable, low maintenance, easy to service. Recommended for municipal and subdivision applications.

BUILDING TYPE STATION



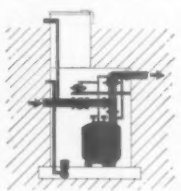
Expelsor® pneumatic ejector station designed for use in buildings. Compressor is on basement floor; ejector on floor below. Sealed installation gives safe, odorless handling of sewage indoors.

SPECIAL PROBLEMS?



Centrifugal vertical wet pit pumps with adjoining settling basin. Good for areas where sand or old sewers create problems. Special pump construction for abrasive or corrosive conditions, industrial wastes.

MAXIMUM RELIABILITY—MINIMUM SPACE



Package underground station. Expelsor® pneumatic ejector has two compartments, duplex compressors and controls. Excellent service accessibility. Especially suited for subdivision and municipal lift stations.

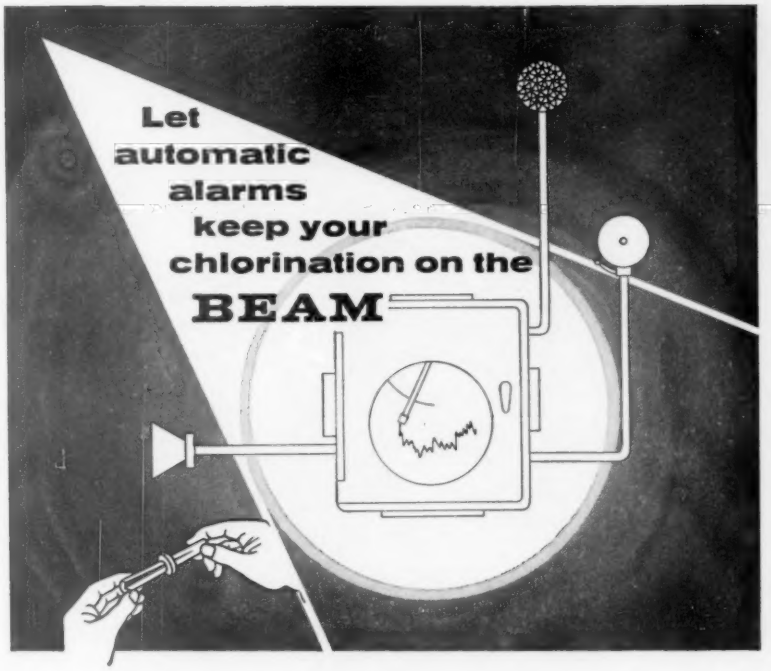
The answer depends on the job. Is it to be a temporary station? What about future loads? How much maintenance will it get? What type of power is available? These and many other questions must be weighed carefully and without bias. In making the decision, why not put Yeomans 61 years' experience (59 on underground stations alone) to work? Because Yeomans builds *the only complete line* of sewage lift stations in the industry, recommendations are *impartial* and in your best interest. Phone, wire, or write now.

L-5911

YEOMANS

1999-7 N. Ruby St., Melrose Park, Ill.

SPECIALISTS IN SEWAGE LIFT STATIONS—THE COMPLETE LINE



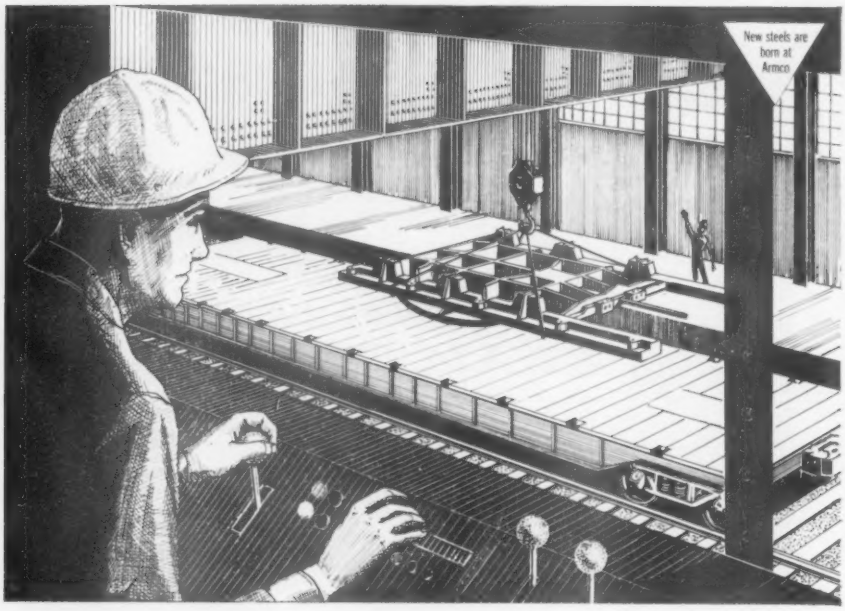
Convert your chlorine system to a system that watches itself, monitors its own results. Conversion is easy with Wallace & Tiernan Automatic Alarms. These dependable warning devices aid in overall operating efficiency . . . give you the final assurance that your system is operating properly, that your water is safe. And these alarms are flexible enough to tie in with any physical layout, any type of signal.

W&T Alarms warn of any deviation from desired performance. You get audible or visible warnings, at or remote from the chlorinator. Alarms warn you of dangerous pressure increases, lowered or exhausted chlorine supply, malfunctions in auxiliary equipment, and other hazards. And, to keep your system "on beam" at all times, alarms show residuals outside pre-set limits.

With automatic alarms by Wallace & Tiernan you avoid dangerous underchlorination and wasteful overchlorination. You save man-hours for more efficient use of personnel.

For more information, write Dept. S-143.84

WALLACE & TIERNAN INCORPORATED
25 MAIN STREET, BELLEVILLE 9, NEW JERSEY



Steel

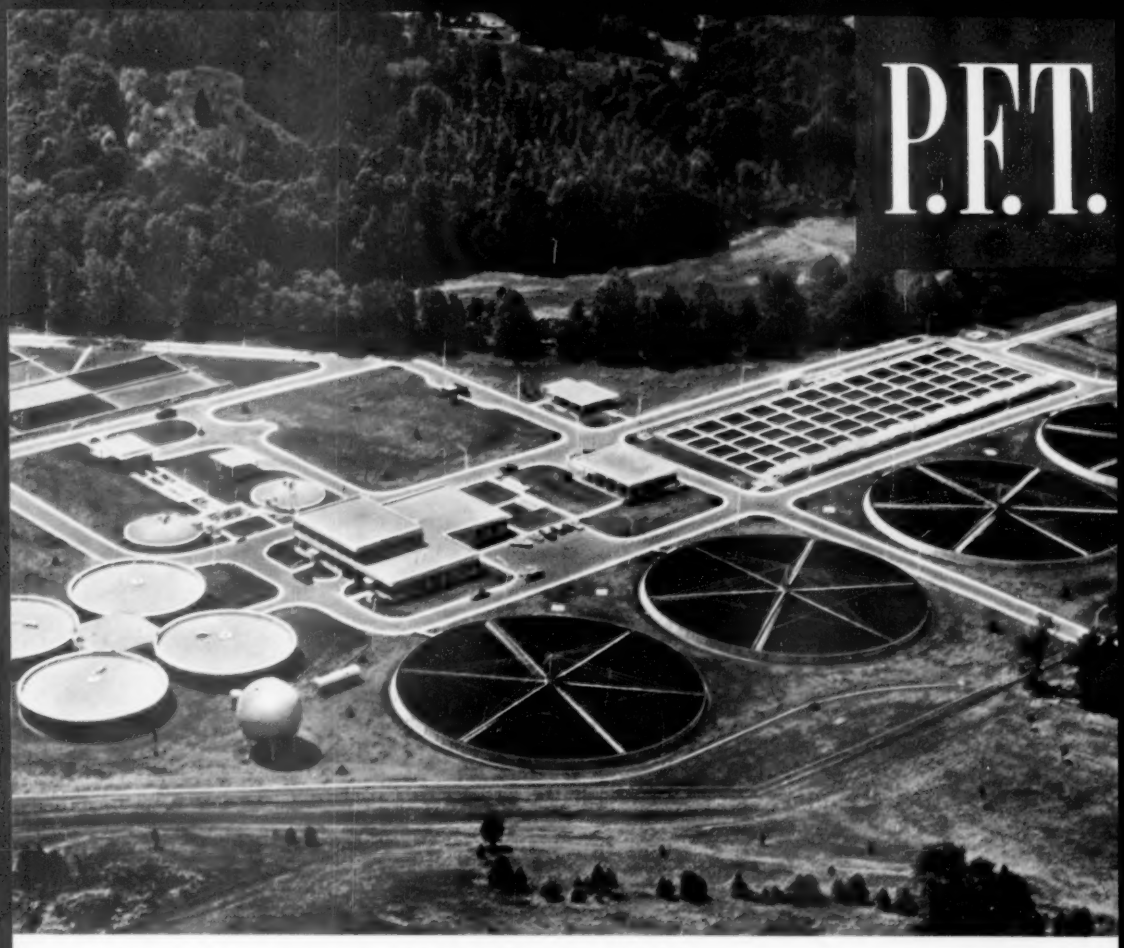
For rugged, dependable economy

When It Leaves On "The 3:01," Your Armco Gate Is Ready To Install

Big or small, every Armco Sluice Gate is completely assembled and adjusted before it leaves for your job site. It arrives as a self-contained unit, and can be quickly mounted by an inexperienced crew with proper supervision. There's no need for high-cost, specialized labor. Detailed instructions for final adjustment are included with *every* gate.

Low installation cost is just *one* of the advantages you get with rugged, watertight Armco Gates. Write Armco Drainage & Metal Products, Inc., 5801 Curtis Street, Middletown, Ohio, for the latest catalog.

ARMCO Drainage & Metal Products



This is Winston-Salem's Waste Treatment Plant Showing P.F.T.'s 200' Rotary Distributors and P.F.T.'s 90' Floating Cover Digesters with P.F.T.-Pearth Gas Recirculation Systems.

Superior Waste Treatment at Winston-Salem . . . . Now and for Years to Come

Winston-Salem, "City of Culture, History and Industry" is a big city with big ideas; ideas that are materializing and consistently shaping the future of this southern metropolis.

In its metropolitan area there are over 280 diversified industries. Here you'll find the world's largest cigarette manufacturing plant—the world's largest men and boys' knit underwear manufacturer—the world's largest circular knit hosiery mills—and—one of the world's finest waste treatment plants.

This "bigness" spells out civic cooperation. In fact, Winston-Salem's motto is "The City Founded Upon Cooperation". Winston-Salem's growth has been planned and these plans are expanding.

All of this tremendous industrial and domestic growth demanded the ultimate in safe sanitation. Here again "the city of cooperation" took action and the construction of this waste treatment plant was the result of present and future-minded planning.

Excellently engineered this waste treatment plant places Winston-Salem among the nation's leaders in fulfilling their obligation not only to the community but its downstream neighbors as well. Winston-Salem knows that modern waste treatment equipment—P.F.T. equipment—and a modern waste treatment plant are truly a civic asset. Please turn the page for the story of P.F.T. at Winston-Salem.

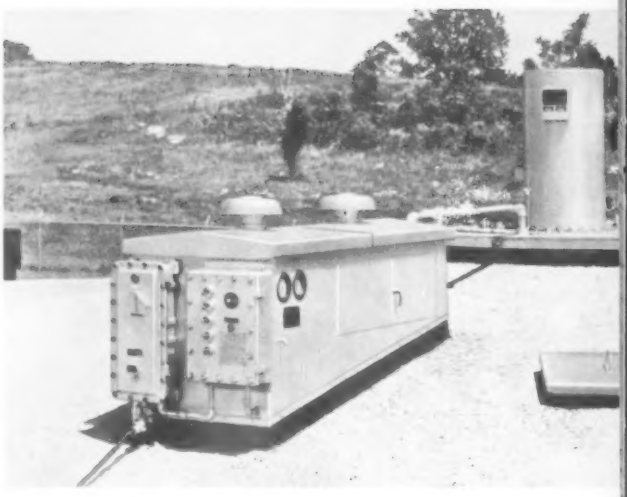
Manufacturers and designers of fine waste treatment equipment since 1893, the Pacific Flush Tank Company take pride in being a major participant in furnishing equipment for the Winston-Salem plant.

P.F.T. Rotary Distributors, 200′ in diameter, are designed to distribute 25.0 mgd of settled sewage uniformly over the entire area of each filter bed. Especially designed P.F.T. bronze forged spreader jets assure the most effective operation of these filters—these biological giants are the heart of this treatment plant.

The four 90′ diameter Digesters are equipped with P.F.T. Floating Covers; three of these units have the P.F.T.-Pearth Gas Recirculation system and the fourth has provisions for the addition of the P.F.T.-Pearth equipment without taking the units out of operation.

External Heaters and Heat Exchanger units by P.F.T. allow complete accessibility in a compact unit of high thermal efficiency. With these P.F.T. #750 heaters uniform temperatures are maintained throughout the digestion system. Other P.F.T. equipment in this digestion system includes Gas Safety Equipment, Supernatant Equipment, Floating Cover Gauge Boards with High and Low Level Alarms.

This P.F.T. "Controlled Digestion System" assures Winston-Salem the most modern installation with full control of the digestion process. Controlled uniform temperatures and positive elimination of scum build-up gives complete utilization of the entire digestion volume for more effective digestion even under the highest solids loadings of the digestion tanks.



One of the three P.F.T.-Pearth Gas Recirculation Systems.

Close-up of P.F.T. Rotary Distributor arm showing P.F.T. Spreader Jets.

P.F.T.

The Winston-Salem Waste Treatment Plant was designed by the Consulting Engineering firm of Piatt & Davis and Associates of Durham, N.C.

waste treatment equipment exclusively since 1893

PACIFIC FLUSH TANK CO. 4241 RAVENSWOOD AVENUE, CHICAGO 13, ILLINOIS

PORT CHESTER, N. Y. • CHARLOTTE, N. C. • JACKSONVILLE • DENVER • SEATTLE • SACRAMENTO • MILLBRAE, CALIF. • LOS ANGELES

NORTH CANTON'S NEW SEWERODER HAS RESERVE CAPACITY FOR FUTURE SEWER ANNEXATIONS

Ohio's new city gears up for growth

A. J. Haun, Water & Sewer Supt., watches SeweRodeR in action as John Fleischman, machine operator, handles simplified controls. Board of Public Affairs, which concurred in selection of the SeweRodeR, consists of Carl O. Sponseller, Pres.; George W. Post, L. Earl Waltenbaugh, Members; and Lester L. Broucher, Clerk.

Rapid growth during the past ten years resulted in North Canton, Ohio becoming a City in 1961. Even faster growth is anticipated through annexations, and the City officials have wisely taken this into account by long range planning.

A major problem created by the rapid expansion is the ability to provide adequate sewer cleaning service for today's needs, plus reserve capacity for the future. After careful investigation, Water & Sewer Supt. A. J. Haun found that by purchasing and truck-mounting a SEWERODER, a single rodding crew could easily maintain the entire system on a preventive maintenance basis. He says, "we find the SEWERODER to be the easiest machine to set up and operate that we have ever had."

The SEWERODER's superior performance is made possible by many unique and exclusive features, such as positive non-slip rod drive, automatic safety clutch, instantly reversible push-pull power. All rods are self-contained in the machine and operating controls are conveniently located. Set-ups are made from street surface by merely lowering the hose guide into the manhole by means of a rope.

FLEXIBLE Inc.

415 South Zangs Blvd., Dallas, Texas
3786 Durango Ave., Los Angeles 34, Calif. • 1005 Spencerville Road, Lima, Ohio

TRUE EFFICIENCY WITH FLEXIBILITY

THE TRUE EFFICIENCY of any type of sewage aerating equipment is best measured in terms of oxygen dissolved into the sewage, not air "delivered" to it. Until the oxygen is in solution, it is not available to the aerobic organisms responsible for purification.

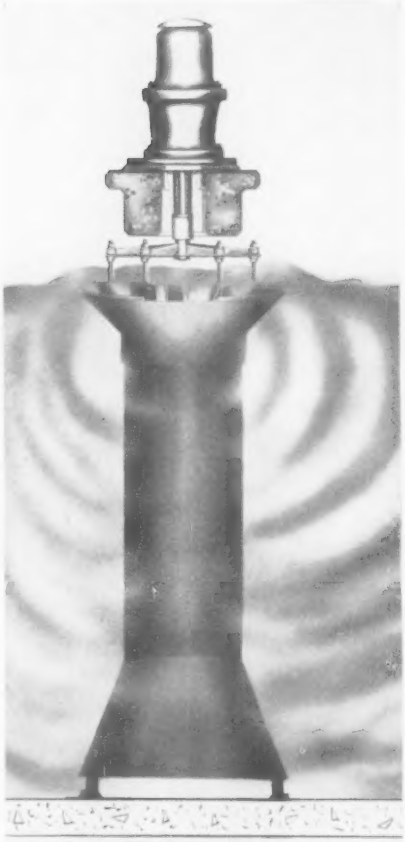
As a result of recent investigations, it is becoming increasingly apparent that oxygen absorption is almost entirely dependent on the rapid and continuous creation of liquid-to-air interfaces. This fact has been long known but not forcibly demonstrated until recently. All oxygen absorption occurs at the liquid "surfaces"—regardless of equipment design or method of aeration.

Therefore, the gauge of efficiency, whatever type of equipment you consider, is "lbs. of oxygen absorbed per KWH."

Compare Hi-Cone's "efficiency rating" with any other aeration equipment. At the same time, investigate the ease with which Hi-Cone handles variations in waste flows and strength through easily adjustable weirs and variable operating speeds. You can get this information by asking your Yeomans representative or the factory for the studies offered at right.

TYPICAL FLEXIBILITY AND EFFICIENCY OF NO. 70 HI-CONE (OXYGENATION CAPACITY—20° TAP WATER)

Inches of Cone Exposure	R.P.M.	Lbs. O_2 Absorbed per Hour at 20° C	NET KW	NET KWH per Lb. Oxygen Absorbed
½	34	37.2	7.0	.188
½	42	57.5	9.9	.172
2	38	38.7	7.3	.189
2	46	54.0	10.0	.185
4	34	27.7	4.9	.177
4	50	54.0	9.5	.176



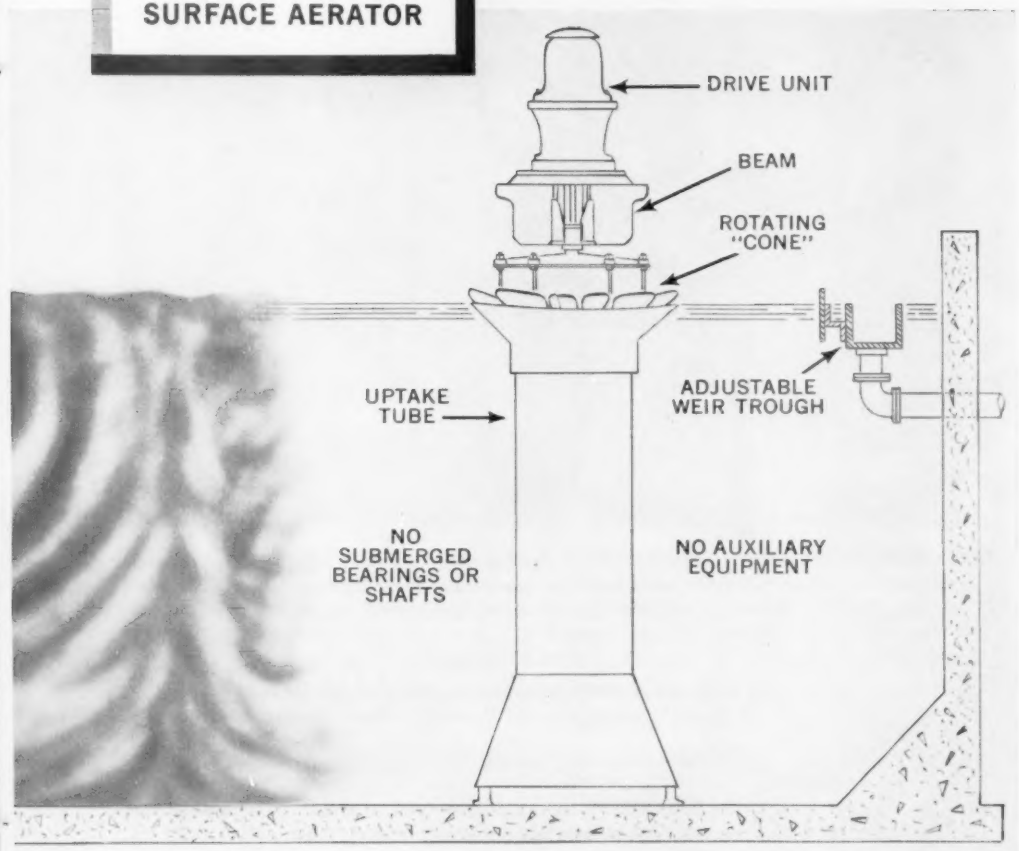
Units for

NOW AVAILABLE!

Basic Data for Evaluating Aeration Equipment

HI-CONE®

SURFACE AERATOR



ALL Sizes of Waste Treatment Plants

- ☐ Activated Sludge Plants
- ☐ Aerobic Digestion Plants
- ☐ Aerator Performance Studies

YEOMANS

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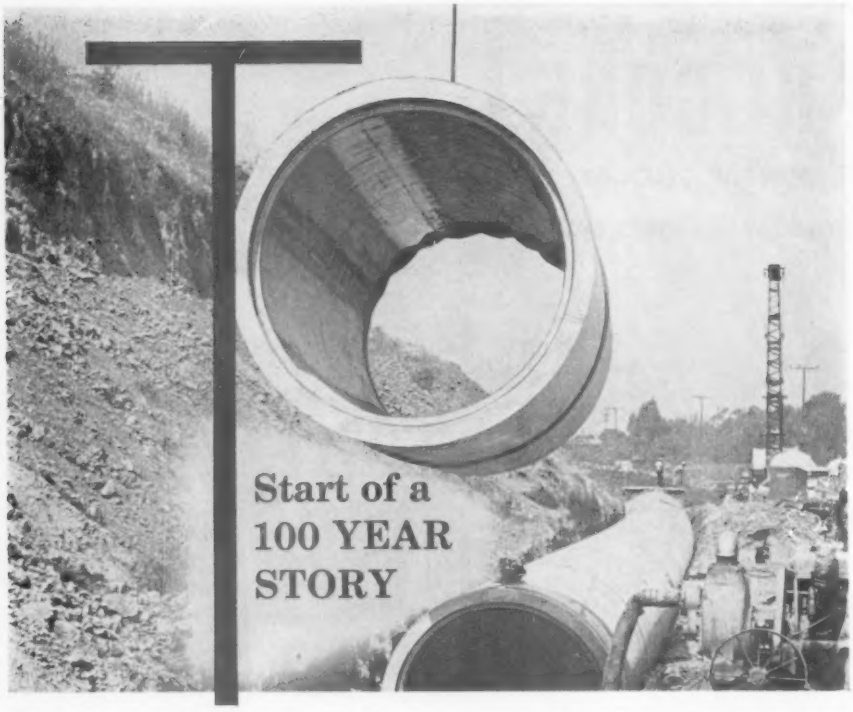
WASTE HANDLING SPECIALISTS FOR OVER 60 YEARS

H-6139



This reinforced concrete sewer will be in service generations from now, because concrete surpasses all other materials. Most concrete sewers do not require protection, but when strong chemical effluents or oxidized H_2S are a problem, only T-LOCK AMER-PLATE provides positive protection. T-LOCK AMER-PLATE is a high molecular weight polyvinyl chloride sheet which is cast into the concrete during manufacture.

T-Lock Amer-Plate meets all the requirements of the ideal sewer lining:

- T-Lock is extremely dense and impervious. Permanently protects concrete from chemical effluents and H_2S corrosion.
- T-Lock is permanently flexible. Tensile strength minimum is 2200 psi; elongation at break is a minimum 200%.
- It is mechanically bonded to the pipe. Pull tests result in the breakage of concrete before T-Lock fails.
- T-Lock withstands 40 psi back pressure, equal to a ground water head of 85 feet.
- T-Lock has a smooth, highly abrasion resistant surface . . . maintains its N factor of .010 indefinitely.

There are no other materials – paints or troweled-on mastics, mortars, sacrificial aggregates or admixes – which meet these vital requirements.

Where protection is required, only T-LOCK will do the job. Compromise methods are a gamble which experienced sewer designers will not take; they know it is money wasted to specify linings which will fail within a few years.

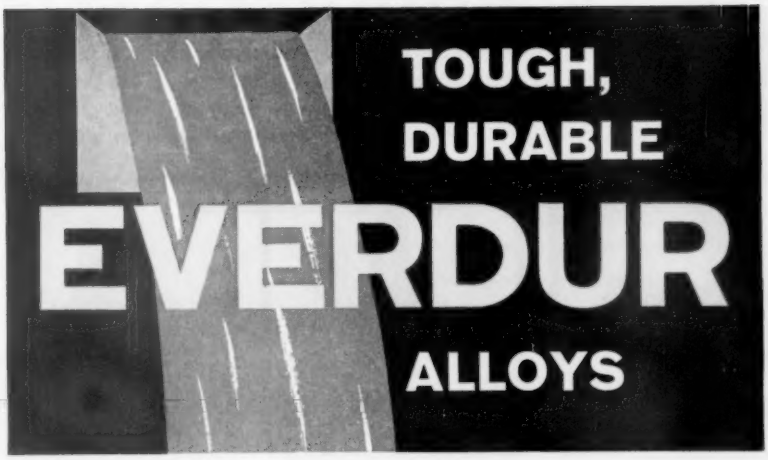
Because T-LOCK AMER-PLATE is the only completely satisfactory material on the market today, millions of square feet are now in use in cities throughout the nation.

Amercoat® CORPORATION

For a complete list of users and specifiers, plus technical data, write:

Dept. SV, 4809 Firestone Blvd., South Gate, California

921 Pitner Ave. Evanston, Ill. | 360 Carnegie Ave. Kenilworth, N.J. | 111 Colgate Ave. Buffalo, N.Y. | 2404 Dennis St. Jacksonville, Fla. | 6530 Supply Row Houston, Tex.



highly resistant to wear and abrasion in sewage and water works systems

EVERDUR® copper-silicon alloys have excellent resistance to corrosion in all types of water works installations and at all stages of sewage treatment operations. EVERDUR equipment in the United States has been in service *without replacement* for 30 years and longer.

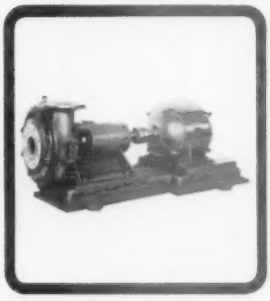
Easily fabricated EVERDUR provides high physical strength with lighter weight. It is used extensively in sewage systems handling corrosive wastes in screens, stems, manhole steps, guides, bolts, weirs, float chambers, troughs. And for water works equipment you will find EVERDUR alloys in long service as surface reservoir outlet screens and screen frames and as large diameter cylindrical well screens in drilled well supply systems. Other uses: spillway fittings, guides, seats and sealing strips. And don't forget EVERDUR Electrical Conduit for use in corrosive atmospheres.

Publication E-11 shows typical applications and other data. Write for your copy—or for assistance from our Metallurgical Dept. in selecting the proper corrosion-resistant alloys for your equipment. Address: Anaconda American Brass Company, Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Canada. 61-811

EVERDUR®
a product of
ANACONDA®
AMERICAN BRASS COMPANY

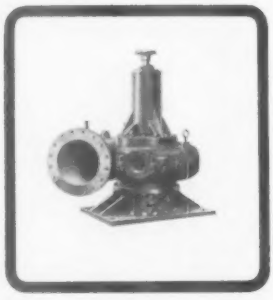
PERFORMANCE-PROVED

Trouble-free years of operation without replacement of major parts, with only routine maintenance, isn't just a claim—C. H. Wheeler pumps are 40 years' performance-proved on the job. (Pumps having higher capacities than those illustrated are available.)



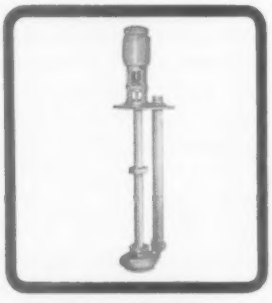
HORIZONTAL NON-CLOG PUMPS. Sewage disposal plants prefer these units for unscreened liquids, sewage. Non-clog impeller, ball bearings, renewable shock absorber. Sizes: 3″—24″. Capacities: 40-5000 gpm. Heads to 160 ft.

VERTICAL NON-CLOG PUMPS in Open-Shaft and Sentry types for dry pit installations. Many engineering advancements bring higher pump efficiency, lower maintenance costs. Service, performance data and sizes same as Horizontal Non-Clog Pumps.



VOLUTE PUMPS OF MIXED FLOW OR NON-CLOG DESIGN are ideal for many pumping applications including: screened sewage, for drainage, irrigation, flood control and industrial water supply. Horizontal and vertical designs available. Sizes: 12″—48″. Capacities: 3000-100,000 gpm.

AXIAL AND MIXED FLOW PUMPS, in horizontal and vertical designs, for flood control, primary water supply, industrial process work, drainage, etc. High-capacity, low-to-medium heads. Standard or pull-out construction. Sizes: 8″—72″. Capacities: 5000-220,000 gpm and over.



NON-CLOG SUMP PUMPS for heavy-duty drainage, underpass service and sewage disposal. Ideal for industrial and municipal lift stations. These pumps have enclosed, non-clog impellers with wide waterways. Sizes: 3″—14″. Capacities: 20-4000 gpm at heads to 160 ft.

C. H. WHEELER MFG. CO.

19th & Lehigh Avenue
Philadelphia 32, Pa.

Affiliates:

The GRISCOM-RUSSELL CO.

•

KLIPFEL VALVES, INC.

Centrifugal, Axial and Mixed Flow Pumps • Ejectors • Steam Condensers • Marine Auxiliary Machinery • Nuclear Components

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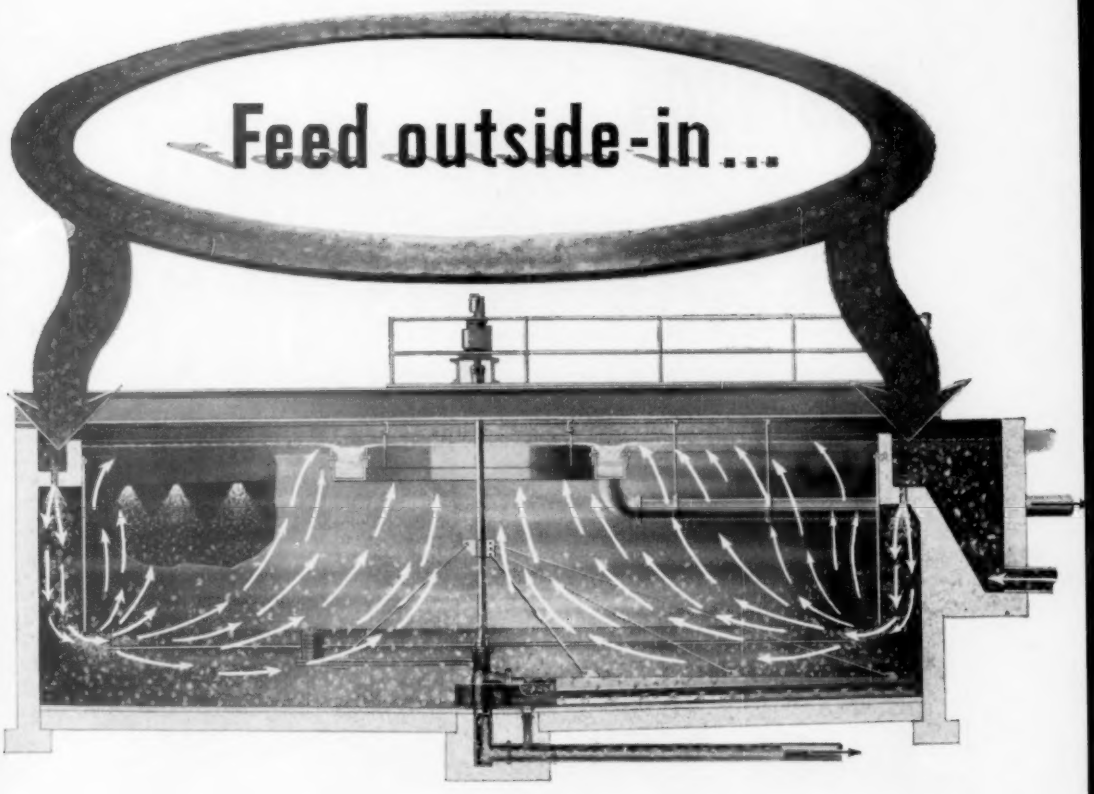
See the Rim-Flo Model Unit in action at Booth Nos. 29 and 30 at the Water Pollution Control Federation Show in Milwaukee.



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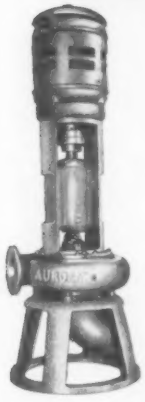

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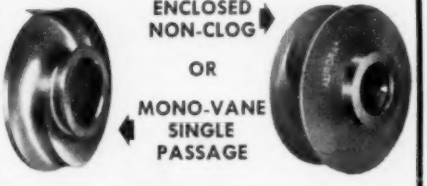

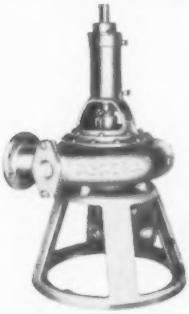

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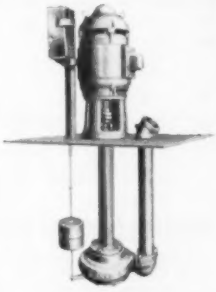

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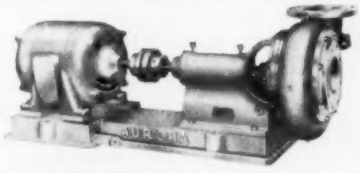

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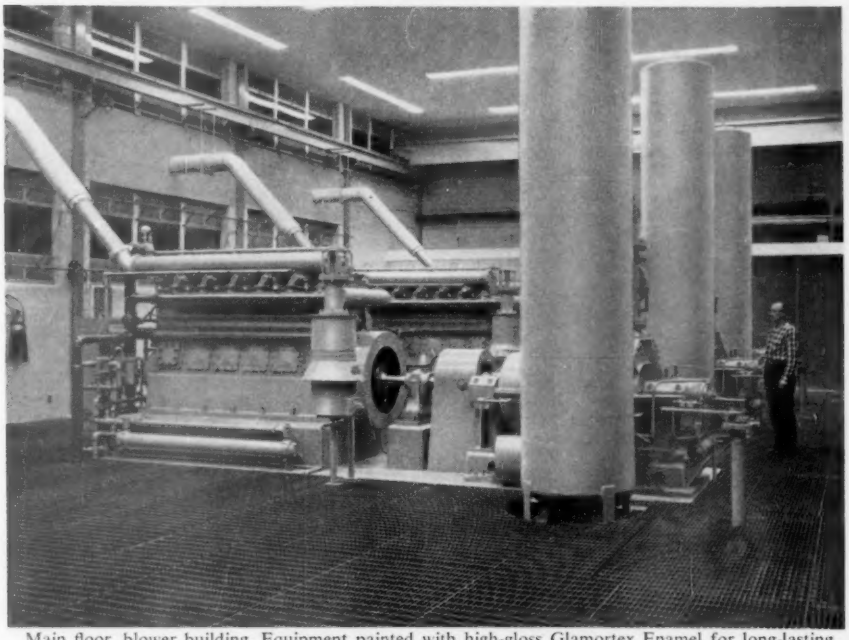

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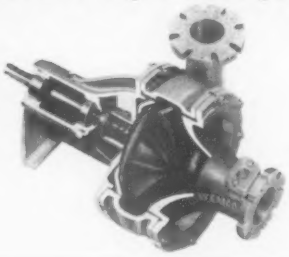

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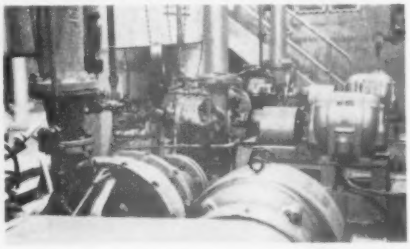

In a new treatment plant enlargement, engineers selected the Wemco Torque-Flow Pump because of sludge containing large amounts of sand, the cause of high maintenance requirements of existing centrifugal pumps. A test installation under varying conditions showed capability to handle the abrasive material without wear, cloggage. This plant now employs eight Torque-Flows for sludge handling and six for digester recirculation.

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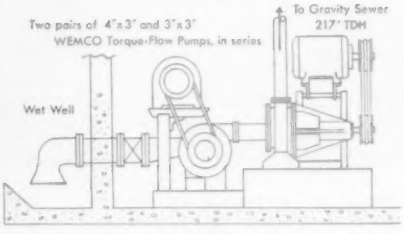

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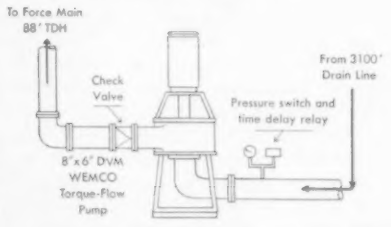

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Photo of Space Ship taken at Freedomland, New York, N. Y.

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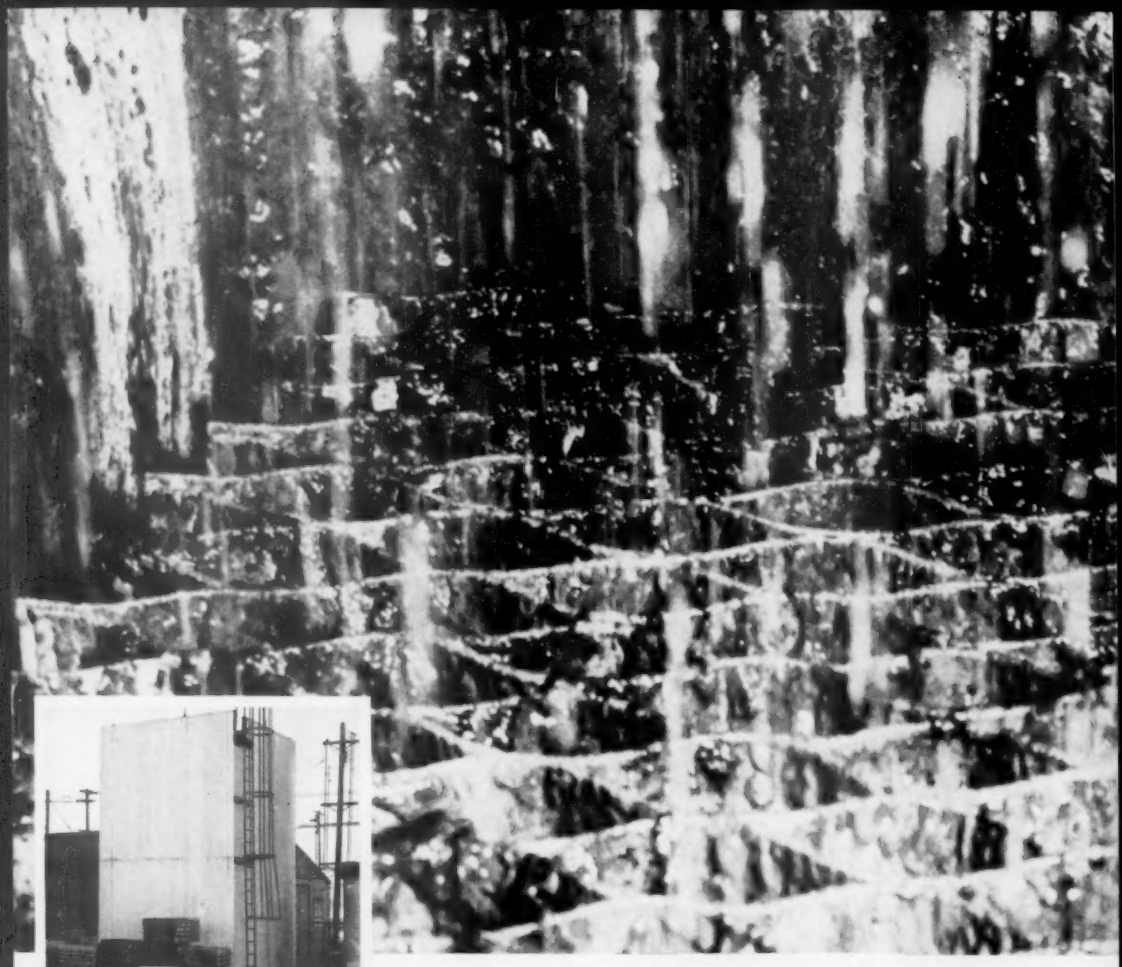

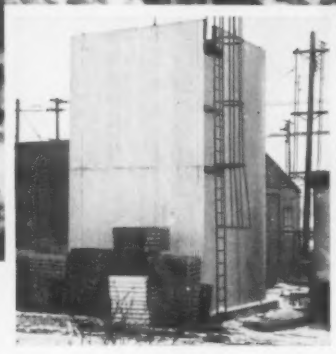

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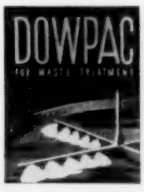

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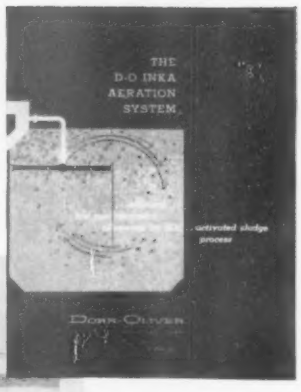

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RAPID COLIFORM ORGANISM DETERMINATION WITH C^{14}

Gilbert V. Levin, Virginia L. Stauss, and Walter C. Hess

The radioisotope test seeks to shorten the time required for coliform organism determination to several hours. It does so by incorporating C^{14} into an appropriate medium, inoculating in normal fashion, and detecting any gas evolved by its radioactivity rather than by waiting for visual evidence.

Since the method was last reported (1), changes in apparatus and procedure have been made. The test may currently be described as follows:

Method

Apparatus

The apparatus includes: 1-in. diameter membrane filter assembly (Figure 1) and 1-in. diameter filters, 1-in. diameter paper absorbent pads, pipets, vacuum pump, shaker, 1-in. diameter by ¼-in. deep aluminum planchets with flat lip ⅛ in. wide (Figure 1), 35 mm by 50 mm cover glasses, hot plate or heat lamp, gas flow geiger counter, and scaler.

Medium

The medium consists of British MF MacConkey broth (2) plus C^{14} formate: 3-per cent lactose, 1-per cent peptone, 1-per cent bile salts, 0.5-per cent NaCl, 0.0012-per cent brom cresol purple with 0.002-per cent C^{14} sodium formate (8mc/mM). Following preparation, the medium may be sterilized by autoclaving for 15 min at 15 psi or by membrane filtration. The medium, in a flask plugged with cotton, is then placed on the shaker and shaken overnight in order to reduce by atmospheric exchange small amounts of $C^{14}O_2$ generated in the sterile medium.

Procedure

An aliquot of the water sample, or an appropriate dilution, is filtered through a membrane filter using the one-inch filter and assembly in conventional fashion. The filter membrane is then placed in a sterile planchet which had been covered with a sterile cover glass. Five-tenths ml of sterile medium are immediately dispensed into the planchet by bulb pipet (Figure 1), immersing the filter, and the cover glass is again seated over the planchet. The planchets and cover slips are arranged on a small flat board for easy carrying as a group (Figure 2). After several samples have been prepared in this fashion, over a span of not more than 5 min, the group is placed in an incubator maintained at 44°C. Several sterile controls are also prepared as a check on sterility of the medium, and to measure the level of non-metabolic $C^{14}O_2$ evolved. After incubating all samples for three and one-half hours, the planchets are removed from the incubator and placed near an equal number of identical planchets, each containing an absorbent pad held in position at the bottom of the planchet merely by the snugness of the fit. Each pad is then moistened with five drops of a settled, saturated solution of barium

Gilbert V. Levin is Vice-President—Engineering, Resources Research, Inc., Washington, D. C.; Virginia L. Stauss is Research Assistant, Department of Biology; and Walter C. Hess is Associate Dean, School of Medicine and Dentistry, Georgetown University, Washington, D. C.

The paper was presented at the Rudolfs Research Conference at Rutgers University, New Brunswick, N. J., June 19–21, 1961.

FIGURE 1.—Apparatus for radioisotope test. Labeled medium is added by bulb pipet to culture planchet containing membrane filter. The planchets, pads, and cover glasses are shown in various stages of assembly. The one-inch membrane filter apparatus is immediately behind the row of planchets.

hydroxide delivered from a five-ml volumetric pipet (Figure 3). One such planchet is inverted over the cover glass of each culture planchet (Figure 3). The cover glass is quickly removed and the planchet with the moistened pad

FIGURE 2.—Group of six coliform organism tests on carrying board. Three of the culture planchets have collection planchets positioned, but cover glasses have not yet been removed. Flask of labeled medium is displayed on carrying board for easy viewing.

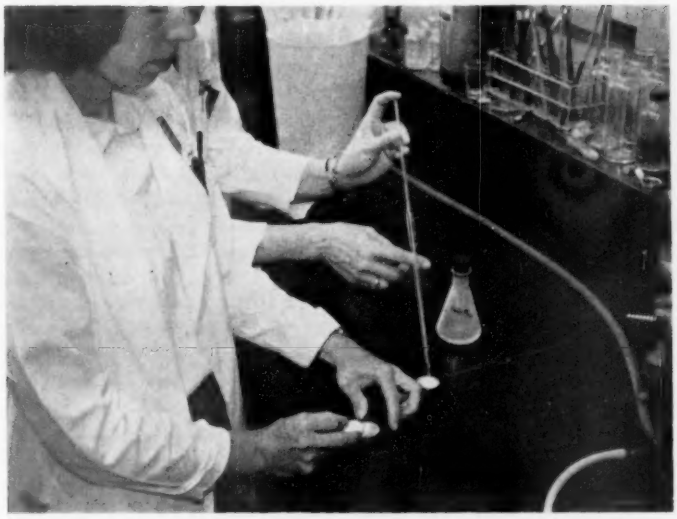

FIGURE 3.—Placing of $C^{14}O_2$ collection planchet. Solution of $Ba(OH)_2$ is added to pad in collection planchet in rear. Collection planchet is being inverted over culture planchet in foreground. Flask contains saturated solution of $Ba(OH)_2$.

placed over the culture planchet. The two planchets thus form a single volume and any $C^{14}O_2$ evolved from the culture planchet diffuses to the absorbent pad in the top planchet where it precipitates as barium carbonate. The paired planchets are then immediately returned to the incubator for 30 min, providing a total incubation period of 4 hr. The planchets are then removed

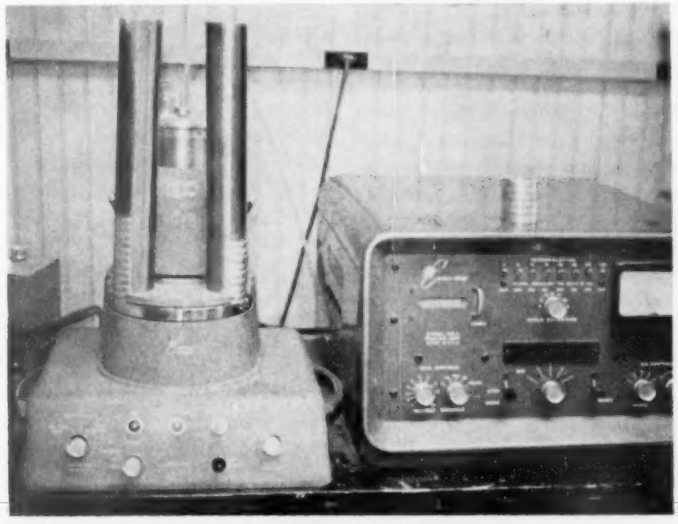

FIGURE 4.—Radioactivity counting equipment. Automatic gas flow counter is to left of scaler.

TABLE I.—Results of Four-Hour Radioisotope Test on *E. Coli* ATCC 8739 Using Nonfiltered Inocula and MF MacConkey Broth

Inoculum (No. Cells)	Avg cpm	cpm/Cell*
12	57	4.75
28	263	9.40
77	625	8.12
83	807	9.73
85	391	4.60
975	7,120	7.30
1,170	5,540	4.73
2,460	16,600	6.75
9,820	70,600	7.19
41,600	211,000	5.08

* Avg cpm/cell = 6.77.

from the incubator and separated. The pads, still in the planchet, are dried for several minutes on a hot plate or under a heat lamp. They are then counted for radioactivity, expressed in counts per minute (cpm), in the gas flow counter (Figure 4). Several drops of disinfectant are added to each culture planchet in preparation for discard. The total activity in each test portion is 1.15 μc and, while it is possible to dispose of the spent medium down the sink, rinse the planchets, and incinerate the pads, preference in this laboratory has been to package all wastes for shipment to a commercial disposer.

Interpretation of Results

Radioactivity in the pads at a level significantly above that of the sterile control pad is evidence of a positive test for coliform organisms. The amount of activity evolved by the organisms is related to the number of cells present. The current phase of the research seeks to define further the specificity of the test and the quantitative aspects.

Characteristics of Test

The radioisotope test is remarkably sensitive. Inocula of only a few cells make themselves known in four to five hours. When labeled formate was first incorporated into MacConkey broth, tube strength broth (3) was used. Later* the British MF MacConkey broth (2) was used. This proved to increase the sensitivity of the test several fold.

Table I presents results obtained with this medium over a wide range of inocula taken from suspensions of *E. coli* ATCC 8739. Each value is an average of 5 replicates with background and sterile control levels subtracted. Except for the fact that the inocula were applied by pipetting 0.1 ml rather than by filtering larger volumes, the tests were performed as described above. Cell counts were determined by nutrient agar pour plates. Here, as throughout this report, cpm/cell are based on the number of cells in the inoculum, not on the cell population at the end of the test period. It is, of course, the number of cells initially present that the test is designed to detect. The data show that the test easily detected 12 cells in 4 hr. This was the smallest inoculum applied in the series. The cpm/cell for inocula ranging from 12 to 41,600 cells showed random differences ranging up to two-fold. Much of this variation might be due to sampling errors incurred in pipetting small volumes of relatively dilute suspensions. The average cpm/cell of 6.77 could be increased by increasing the specific activity of the C^{14} formate. However, while some such increase may be feasible, it is desired to maintain the radioactivity associated with the test at a level low enough to preclude special handling precautions.

While the sensitivity data indicate a significant potential for the test, a number of important problems remain to be solved. Replicates run simultaneously seldom produce results whose spread exceeds a factor of two. However, tests performed with suspensions prepared at different times can produce

* At the suggestion of Dr. E. Windle Taylor, Director of Water Examination of the Metropolitan Water Board of London, England.

more widely ranging results, on occasion approaching an order of magnitude. Moreover, some strains of coliform organisms produce differing epm/cell. The full extent of these differences and the importance of the strains producing them are not yet known. The specificity of the test has not yet been established and it is known that at least *Pseudomonas* and *Alcaligenes* interfere to some extent. Recently, this interference has been much reduced and, as can be seen from data herein, in the order of 1,000 cells of these species are required to equal the response from one cell of *E. coli* ATCC 8739. Finally, a problem exists relating to the use of the membrane filter to concentrate the organisms for inoculation. Because of the importance of the membrane filter to the development and ultimate use of the radioisotope test, this has been studied in some detail.

For reasons which will be discussed presently, it is believed that some of these difficulties also operate against currently accepted standard coliform determination procedures.

Calibrations

A frustrating need in the current phase of the research is the lack of an absolute coliform organism determination method against which to calibrate the radioisotope test. In order to establish the relationship between the quantity of $C^{14}O_2$ collected and the number of organisms initially present in the sample, that number must be known accurately. The great sensitivity of the radioisotope method makes it imperative to calibrate the test against a highly accurate cell count.

With pure cultures, this seems to offer little difficulty when the pour plate technique is used. However, the actual calibration must be carried out in mixed cultures of random composition encountered in surface waters. It then becomes necessary to determine the number of coliform organisms present in the unknown sample in order to check the specificity and quantitative aspects of the radioisotope test.

Thought was at first given to use of the Standard Methods MPN test (4). However, the statistical errors inherent in the method, as cited by McCarthy *et al.* (5), are too great to permit using the MPN test as a standard.

Use of the membrane filter technique seemed the most plausible way to obtain the information needed. When an aliquot of the sample was filtered for the radioisotope test, another portion could be analyzed by the membrane filter test. The results of the membrane filter test would become available the following day and the number of coliform organisms that had been present in the radioisotope test could be ascertained.

There was additional logic in standardizing against the membrane filter test. In the early stages of developing the rapid test, the test medium was inoculated by pipetting aliquots from prepared suspensions of coliform organisms. As research on the method progressed, it became desirable to test samples of water with relatively few coliform organisms. Portions taken directly by pipet or other means from the water to be tested could not provide a representative sample. It thus became necessary to concentrate the bacteria from such waters before inoculating the radioactive medium. The membrane filter seemed to provide a readily available means for collecting all organisms present in a sample of sufficient volume to insure statistical reliability.

The radioisotope procedure was modified accordingly, and the water sample was filtered through a membrane filter which was placed directly in the culture chamber and immersed in the labeled medium. Equal nonfiltered inocula were put through the procedure initially for comparison. It was immediately apparent that those cultures which had been filtered invariably evolved much less $C^{14}O_2$ on a per cell

basis than did the cultures which had not been collected on the filter membrane.

Investigation of Membrane Filter Effect

The following set of experiments was performed to investigate the difference between filtered and nonfiltered inocula in greater detail.

Filtered Inocula

Pure cultures of the test organisms cited below were grown for 24 hr in nutrient broth. A suspension of the culture used was made and serial dilutions prepared. Ten-ml portions of the appropriate dilution, based on experience, were filtered through 25-mm diam membrane filters using commercially available filter assemblies. In this manner, groups of six replicates each, with sterile controls accompanying each test group, were prepared. Five such groups were prepared for each culture. Using tube-strength MacConkey broth, because this work began before the use of MF MacConkey broth was introduced, the radioisotope procedure described earlier was then carried out with the following exception. At 1½ hr, 1 group of 6 tests and 3

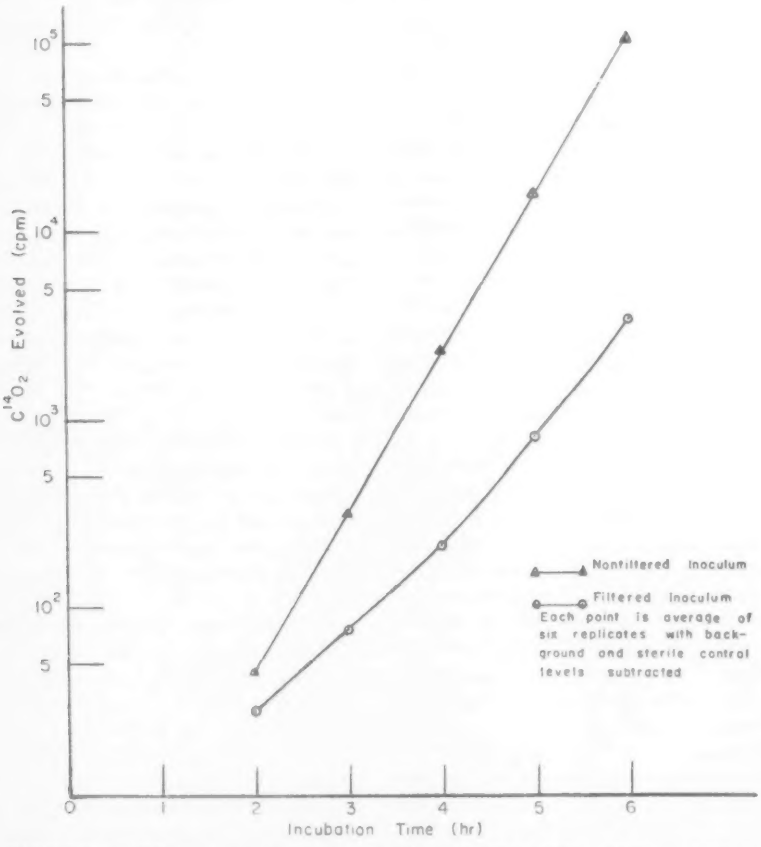

FIGURE 5.—Effect of membrane filter on *E. coli* ATCC 8739. $C^{14}O_2$ evolved as a function of time for filtered and nonfiltered equal inocula.

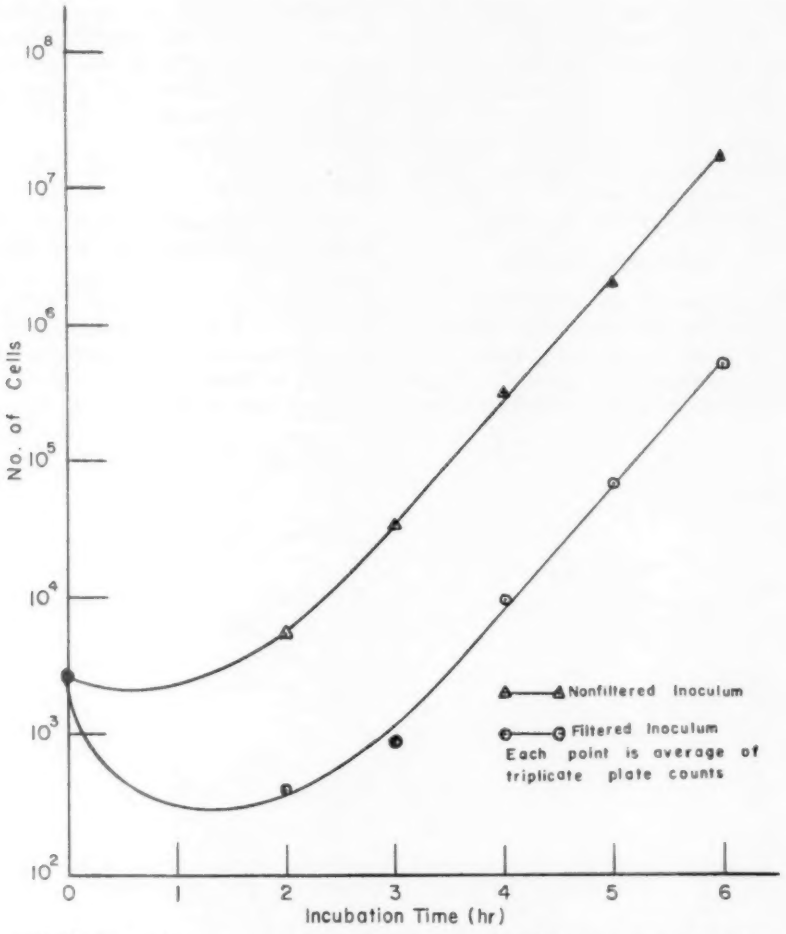

FIGURE 6.—Effect of membrane filter on *E. coli* ATCC 8739. Cell population as a function of time for filtered and nonfiltered equal inocula.

controls were removed from the incubator. Planchets containing the barium hydroxide moistened pads were inverted over each culture planchet and the cover glasses removed. The group was then returned to the incubator. Total time out of the incubator for this operation was approximately two minutes. One-half hour later, after a total elapsed incubation period of two hours, this group was removed from the incubator. The paired planchets were immediately separated and the planchets containing the barium hydroxide impregnated pads were dried on a hot plate. In this manner, the five equally inoculated groups were incubated for two, three, four, five, and six hours, respectively. In each case, collection of the $C^{14}O_2$ was made during the terminal one-half hour of incubation.

As soon as the paired planchets in each group were separated at the termination of the incubation period, the planchets containing the filters and cul-

tures were placed into a single flask containing a measured volume of buffered sterile water and shaken vigorously. Triplicate nutrient agar pour plates were then made directly from the flask and from serial dilutions made from the suspension in the flask. These pour plates were incubated 24 hr and the bacterial colonies counted.

Nonfiltered Inocula

The procedure was the same as that described for filtered inocula except for the method of inoculation. Inoculation was accomplished by pipetting 0.1 ml of the serial dilution 100-fold more concentrated than that dilution used in the filtered runs. This provided equal inocula to the filtered and pipetted tests. The cell counts were determined by triplicate pour plates of serial dilutions of the culture.

Test Organisms

Three test organisms were selected: *E. coli*, *Pseudomonas sp.*, and *Alcaligenes sp.* *E. coli* ATCC 8739 was selected as a typical coliform. The *Pseudomonas sp.* and *Alcaligenes sp.* were selected because they were isolated from cultures of Potomac River water and had seriously interfered with the spe-

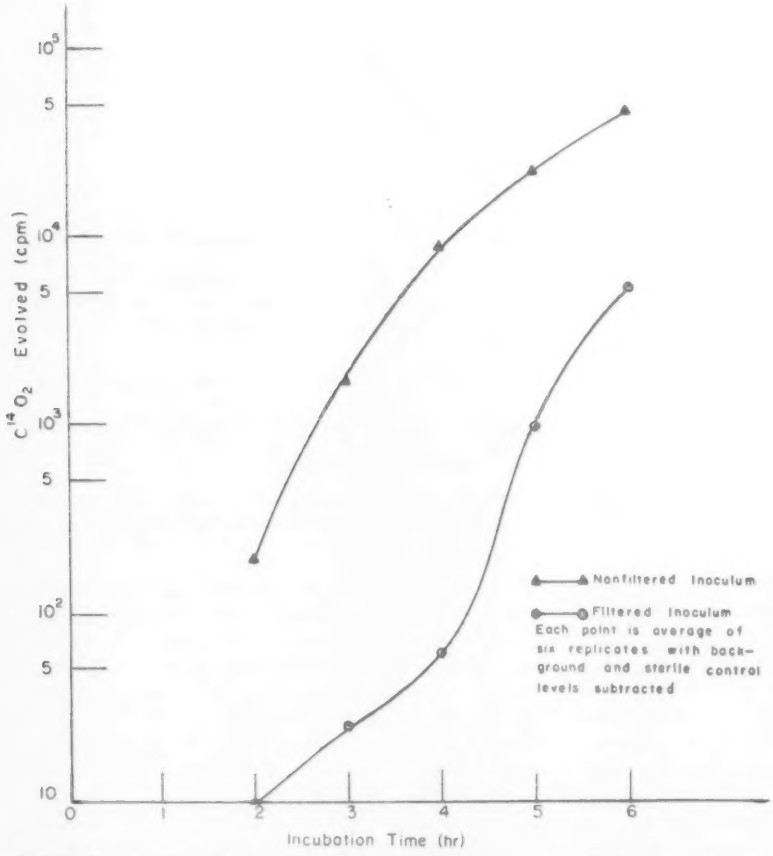

FIGURE 7.—Effect of membrane filter on *Pseudomonas sp.* $C^{14}O_2$ evolved as a function of time for filtered and nonfiltered equal inocula.

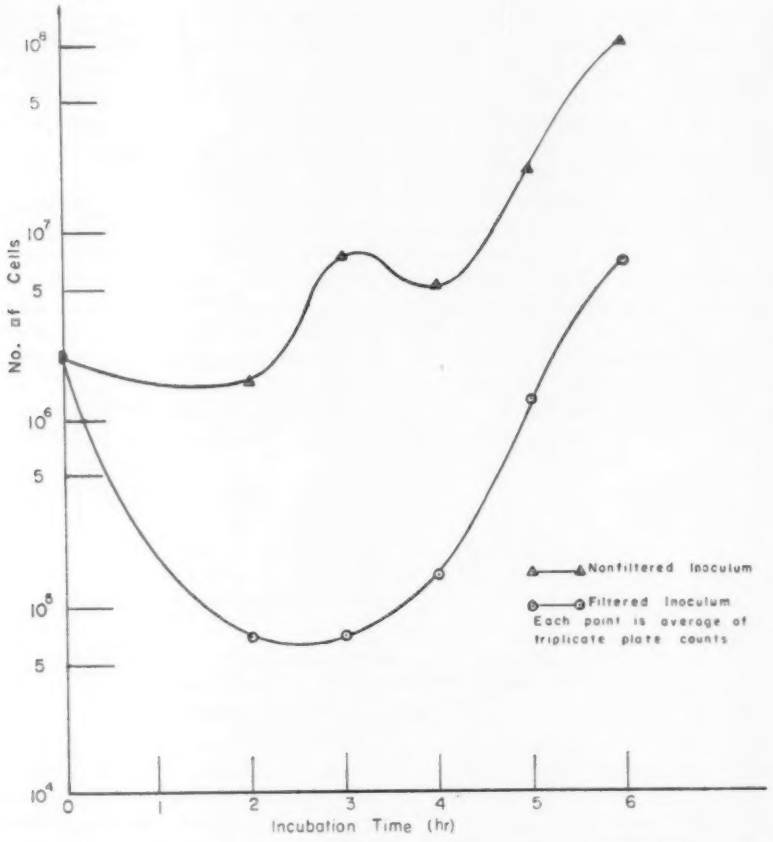

FIGURE 8.—Effect of membrane filter on *Pseudomonas sp.* Cell population as a function of time for filtered and nonfiltered equal inocula.

cificity of the coliform test in earlier work.

Results

The results obtained are presented graphically in Figures 5 through 10. Figure 5 shows that the effect of the filters on *E. coli* was to reduce the amount of carbon dioxide evolved from the cultures. At 4 hr this amounted to almost a 10-fold effect and at 6 hr, the termination of the experiment, the difference between the amount of gas collected from the filtered and nonfiltered cultures exceeded 30-fold. This curve is of great interest in that its exquisiteness demonstrates the inherent precision of the radioisotope technique in monitoring metabolic activity. Figure 6 shows the effect of the filter on cell reproduction as a function of time. When the inoculum had not been filtered, the cells underwent a slight lag and then began reproducing. Before the elapse of two hours, the cultures were in exponential growth. The filtered cultures showed a high rate of mortality during this first two-hour period. The surviving organisms then began reproducing but did not achieve exponential growth until the third hour. When the curves became par-

allel, at the third hour, the difference in cell numbers between the 2 types of cultures was 30-fold. This 30-fold effect was maintained throughout the remainder of the 6-hr experiment.

The sensitivity of the test for a given incubation period may be determined here, and for the experiments which follow, by dividing the cpm at the time of interest by the zero time cell count.

The $C^{14}O_2$ curves with *Pseudomonas sp.* are somewhat different as seen in Figure 7. The initial loss of cells, Figure 8, and consequent loss in $C^{14}O_2$ evolved is similar to that obtained with the coliform organisms, but the curves produced by the filtered cultures and nonfiltered cultures do not diverge with time. It is also evident from both curves that the *Pseudomonas sp.* did not respond as well in the test as did the *E. coli*, as would be expected from the selective characteristic of the medium.

In the case of the *Alcaligenes sp.*, Figures 9 and 10, it is again apparent that the selective nature of the medium inhibits both the filtered and nonfiltered cultures. Nonetheless, a marked difference in response is evident between the filtered and nonfiltered cultures.

This evidence that the membrane filter had an inhibitory or even toxic ef-

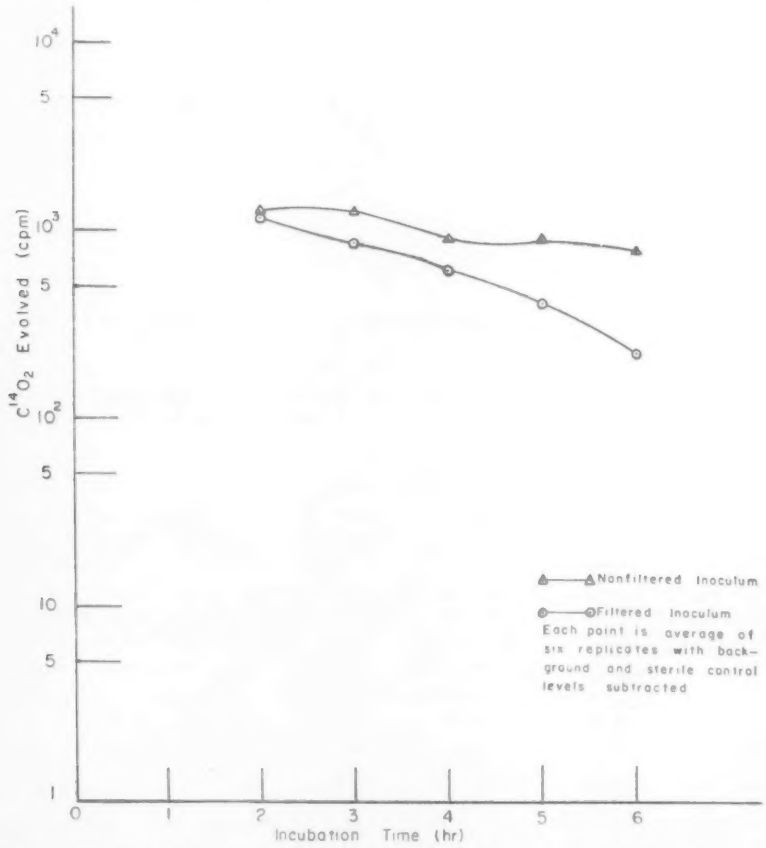

FIGURE 9.—Effect of membrane filter on *Alcaligenes sp.* $C^{14}O_2$ evolved as a function of time for filtered and nonfiltered equal inocula.

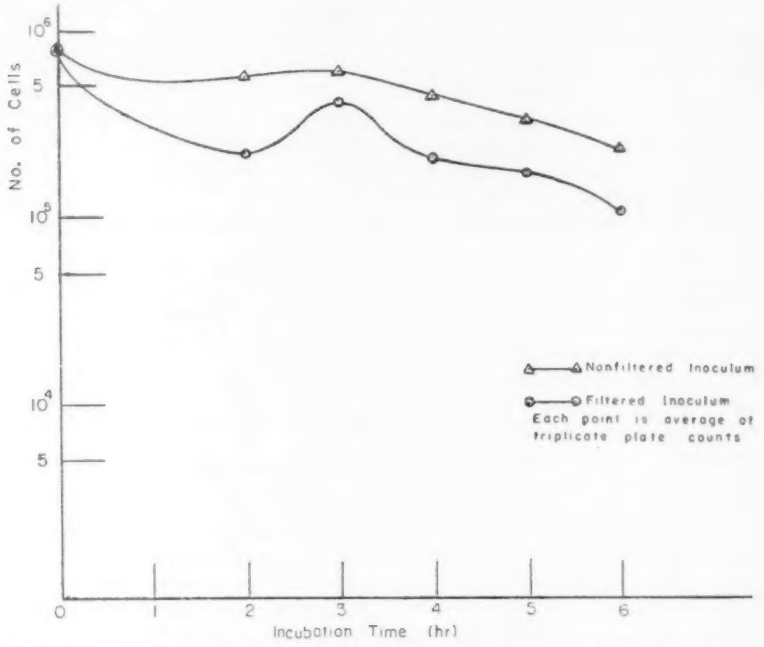

FIGURE 10.—Effect of membrane filter on *Alcaligenes sp.* Cell population as a function of time for filtered and nonfiltered equal inocula.

fect on bacteria constituted an unforseen and unwelcome obstacle to the development of the radioisotope test. Furthermore, the results were difficult to reconcile with the published literature on the membrane filter. Experimental work was continued in this vein. At the same time the literature was watched for evidence of a membrane filter effect.

Wolochow (6) provided the first supporting evidence in his account of erratic results obtained with various organisms in membrane filter determinations. He investigated several possible variables, none of which pinpointed the cause, but he felt the difficulty was due to both the media and the filter membranes. McCarthy *et al.* (5) pointed out that some bacteriologists believe the MF technique gives false positives and inhibits the growth of certain members of the coliform group. While these investigators clearly established the statistical problems in the MPN test, they did not report on the bacteriological reliability of the MF test. Henderson (7) reported differences, approaching 10-fold, between the MF and MPN on replicate coliform determinations with low numbers of cells. The differences tended to increase with increasing cell population. He reduced the discrepancy on the basis of statistical error in the MPN test, but even then the results remained several fold higher than the MF results, and the trend for wider discrepancy with increased cell population remained. Henderson, however, compared replicate MF and total plate counts of coliform organisms and found good agreement. He concluded that the MF is accurate on the basis of the correlation found with the pour plate technique.

Similar comparison was attempted in this work without success in duplicating agreement between the two meth-

ods. Using M-enrichment broth followed by brilliant green fuchsin broth in some instances and the one-step m-endo broth MF in others, standard (3) MF determinations were made using *E. coli* ATCC 8739. The results were compared with nutrient agar pour plate determinations. A total of 113 MF determinations were made with inocula ranging from 22 to 565 cells, as determined by replicate pour plates. Agreement between averages of replicates of test groups fell within 20 per cent, based on the pour plates, in only 6 of the groups, comprising 35 of the 113 MF determinations. The differences for the other groups ranged up to 15-fold in 2 instances and were several fold in others. For only 2 groups, both being of those groups agreeing within 20 per cent with the corresponding pour plates, did the average MF count exceed the average pour plate count.

Recently Malaney *et al.* (8) reported large discrepancies between MF and MPN coliform determinations when the confidence limits of the MPN were based on the Poisson distribution to correct for the statistical error inherent in the MPN test using five tubes in each of three dilutions. In the study reported, the mean MPN result exceeded the MF mean by at least six-fold. Moreover, by the 95-per cent confidence limits established, agreement between the two methods occurred in less than one-third of the cases. Finding the number of false positives in the MPN confirmed test to be greater than expected, Malaney *et al.* (8) compared the MPN confirmed test, the Standard Methods completed test, and the MF. The MF results were found to be roughly four times as high as those of the completed test, and the MPN results approximately nine-fold greater than those of the completed test. They believe the Standard Methods completed test to be the most accurate of the three.

In an attempt to determine the bactericidal factor associated with the membrane filter, filters were placed in nutrient broth and heated in order to extract any toxic material that might be present in the filter. When the filters were removed and the broth used, coliform organisms grew as well as in freshly prepared broth.

Possible Rupture of Cells

One obvious possibility that might account for the loss of cells in the filtered cultures is mechanical rupture of the cells as they are impacted against the membrane pores during filtration.

To investigate this, the following experiment was performed:

Filtered Inocula

A manometer and an air by-pass valve were placed into the train of the membrane filter apparatus in such manner that the vacuum applied could be measured and controlled. A suspension of *E. coli* ATCC 8739 was prepared and served as the inoculum pool. Filtrations of 10-ml portions were made in sextuplicate under vacuums of 5, 10, 20, and 29 in. of mercury.

Pipetted Inocula

A 0.1-ml portion of a 100-fold less diluted suspension of the same culture preparation from which the inocula for filtration were prepared was pipetted into each of six culture planchets. Sterile membrane filters were merely placed into 6 other planchets and 0.1-ml portions of the coliform organism suspension were placed on top of the membranes by pipet.

Tagged MF MacConkey medium was immediately added to all culture planchets which were then incubated for four hours at 44°C. The cover slips were removed and collection of the evolved gas occurred during the last 30 min of the incubation period. Triplicate sterile controls were run in the presence and absence of the filter membrane. The inocula were determined by triplicate plate counts.

TABLE II.—Effect on *E. Coli* ATCC 8739 of Culturing After Impaction on Membrane Filter vs. Mere Proximity to Membrane Filter

Item	Counts Per Minute							
	Pipetted Inocula		Filtered Inocula				Sterile Controls	
			Vacuum (in. Hg)					
	− filter	+ filter	5	10	20	29	− filter	+ filter
—	11,100	6,110	755	960	648	590	44	50
—	13,800	4,020	614	625	604	590	59	60
—	11,600	3,470	416	1,030	731	445	42	39
—	11,600	3,330	498	1,050	671	435	—	—
—	12,800	4,800	387	590	980	830	—	—
—	14,600	3,870	597	715	875	860	—	—
Avg	12,600	4,600	545	820	750	625	48	50
No. cells in inoc.	2,800	2,800	2,040	2,040	2,040	2,040	—	—
cpm/cell	4.50	1.64	0.27	0.40	0.37	0.31	—	—

Results

Table II presents the results of the experiment. It is shown that the mere presence of the filter in the culture reduced the amount of gas evolved by approximately three-fold. The effect of the filters on the cultures which had been impacted against them was much more drastic and constituted an average reduction in gas evolved of approximately 10-fold. There was no relationship between degree of vacuum applied and gas production, with a vacuum of only 5 in. of mercury having essentially the same effect as one of 29 in. The sterile controls are of interest here in that the same amount of nonmetabolic $C^{14}O_2$ was evolved from the medium when the filter was present as when it was not. This demonstrates that the reduction in gas evolved from the cultures is not due to adsorption and retention of the gas on the filter surface.

These data, in conjunction with the cell survival data cited, leave no doubt that the bacteria suffer a real effect from the presence of the filter membrane. The cell mortality observed is caused by at least two factors. First, damage to cells is incurred when suspended cells are impacted on filter membranes. This damage may result from simple mechanical rupture of the cell wall. Second, however, the mere presence of the membrane in close proximity to or in contact with the cell exerts a pronounced effect. This effect is more difficult to explain.

It was conceivable that the cell survival data were open to question on the grounds that those cells unaccounted for did not die, but adhered to the filter and did not come off during resuspension. If so, they would not have been counted when the resuspended culture was plated. Wolochow (6) has reported on this difficulty in resuspending cells impacted on the membrane filter. However, it is extremely unlikely that a a sufficiently high percentage of new generations of cells would stick to the membrane to produce the results obtained in the later hours of the test runs. Nonetheless, the possibility that cells not impacted on the filter membrane, such as new cells generated from those initially collected by the filter, might be strongly attracted to the filter membrane was investigated. One milliliter of a 10^7 dilution of a 24-hr nutrient broth culture of *E. coli* ATCC 8739 was pipetted onto 47-mm sterile filter membranes placed in sterile petri

TABLE III.—Numbers of Unimpacted *E. Coli* ATCC 8739 Adhering to Membrane Filter

Item	1 ml Inoculum Pipetted onto MF		0.2 ml Inoculum No MF Present (per ml)
	Cells Remaining on MF	Cells Remaining in Petri Dish	
—	9	727	154×5=770
—	48	741	165×5=825
—	29	728	152×5=769
—	22	767	—
—	19	718	—
—	27	755	—
—	18	759	—
—	29	742	—
—	27	737	—
Avg/ml	25	742	785
Total cells/ml	767	767	785

dishes. After standing several minutes, the filter membranes were removed and incubated in m-endo broth MF according to the standard MF procedure. Nutrient agar was poured into these petri dishes and into ones that contained no filter but had received 0.2 ml of the same suspension. The results are presented in Table III. Only about three per cent of the cells adhered to the filter membranes. This was additional evidence that the differences in cell populations reported for filtered and pipetted tests were not due to the incomplete removal of cells from the filter membrane. The probability that the differences were due to inhibitory or toxic effects of the filter membrane was therefore strengthened.

Filter Brands

To determine whether the filter membrane effect might be due to a characteristic of the S and S brand filter being used, the available commercial brands were compared. Replicate testing was performed with S and S, Millipore, Oxoid, and Gelman Type 27A filter membranes. No appreciable differences were found between the effects of the first three brands. The Gelman Type 27A filter, however, exhibited a much less pronounced adverse effect. Typical results for a test of six replicates each with equal inocula of *E. coli* ATCC 8739 showed an average of 650 cpm for the S and S filters versus an average of 1,800 cpm for the Gelman Type 27A filters. Because of this difference, an extended test, similar to those reported in Figures 5 through 10, was made with this strain of *E. coli* to compare results obtained with pipetted and Gelman-filtered inocula. The data are presented in Figures 11 and 12. Correlation is seen to be much better than with the tests made with other filters. The filter effect was reduced to approximately two-fold for cpm evolved. Agreement between cell numbers obtained with and without filters improved similarly. This encouraging and important difference in membranes warrants further investigation.

Discussion

The observations reported herein are at variance with numerous initial reports on the membrane filter method for coliform determination. The salient difference between this work and the standard method for coliform determination by the membrane filter is that here MacConkey broth was used and incubated at 44°C in accordance with the MacConkey method, while the standard MF method uses other lactose-base media with incubation at 35°C. For the purpose reported, the standard MF media will not do in that their specificity relies on color rather than gas production. It may be, therefore, that with the recommended MF media, cell survival and reproduction would have been greater than that reported herein. However, in a comparison between the standard MF test and pour plates, the data obtained did not so indicate. Furthermore, a logical explanation for the fact that the filter membrane would be inhibitory or toxic in one medium and not in another seems difficult to formulate. It has not been learned

why the cells responded differently in the presence of the filter membrane than in its absence.

Future Plans

By utilizing the Gelman Type 27A filter and perhaps extending the length of the test another hour to compensate for this minimized filter effect, it is planned shortly to begin testing raw and finished water samples. The results will be compared to those obtained from the same samples by the standard MF test. For the reasons cited and the cautions expressed by the prescribed Standard Method (4) MF test for coliform organisms, this comparison will not be made without hesitation. However, no more precise method for making the comparison is available.

It is encouraging that other investigators are now working on the radioisotope test. Among the laboratories conducting research on the method are those of the Illinois State Health Department (9), the Metropolitan Water Board of London, and The Liverpool College of Technology, and L. Lyons and Company, Ltd., of London (10). Further work based on the method is being done in the Department of Microbiology of the Georgetown University, School of Medicine and Dentistry (11) in an attempt to develop a rapid test

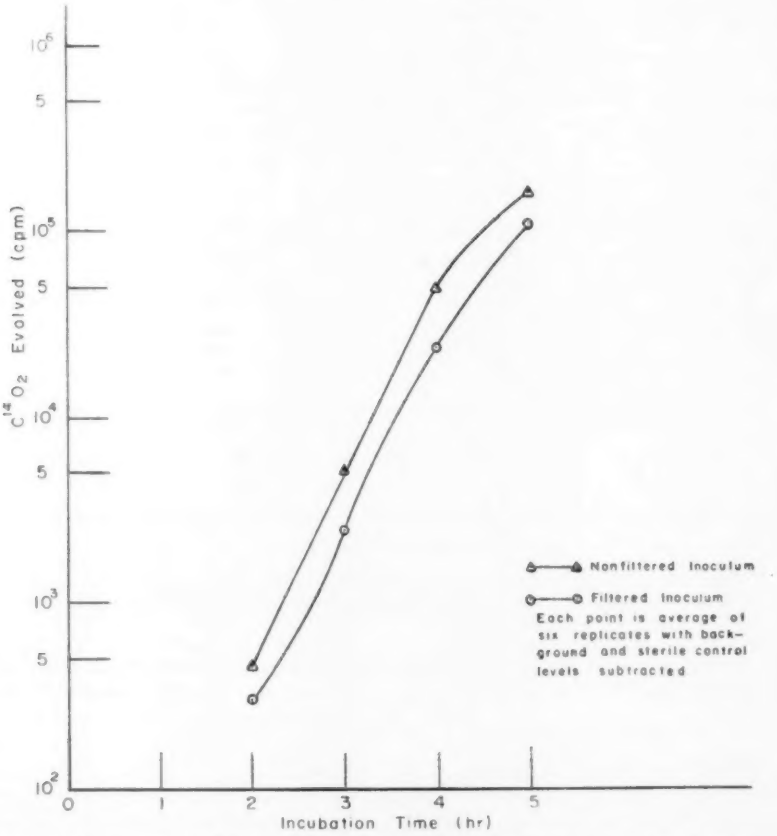

FIGURE 11.—Effect of Gelman Type 27A membrane filter on *E. coli* ATCC 8739. $C^{14}O_2$ evolved as a function of time for filtered and nonfiltered equal inocula.

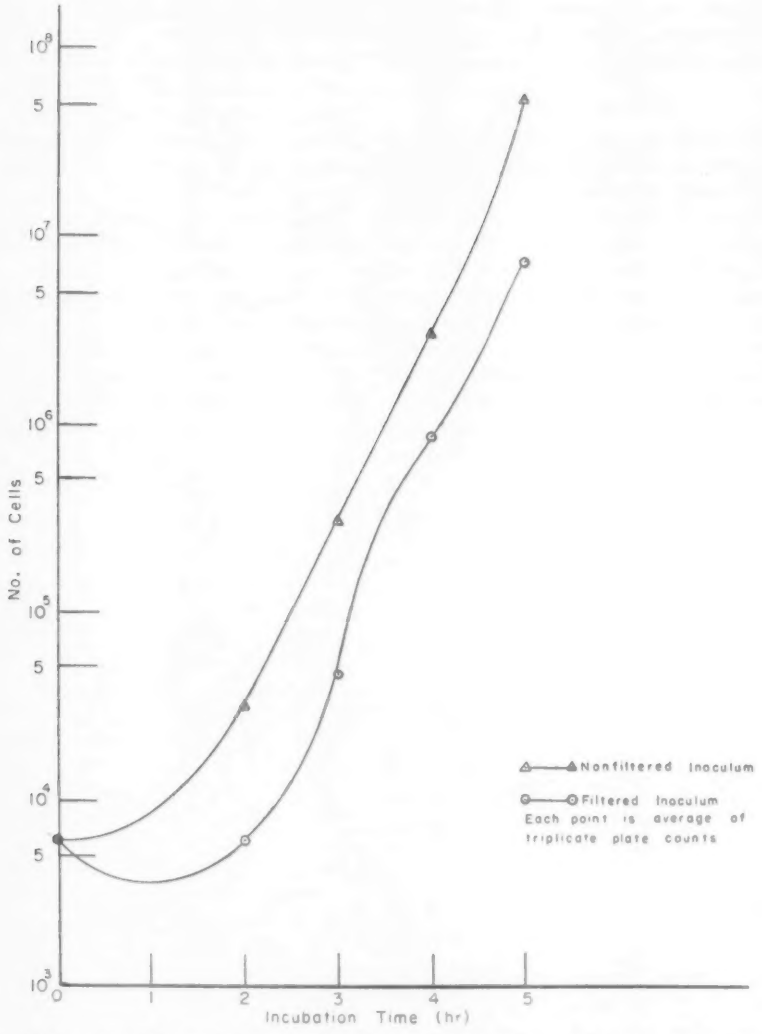

FIGURE 12.—Effect of Gelman Type 27A membrane filter on *E. coli* ATCC 8739. Cell population as a function of time for filtered and nonfiltered equal inocula.

for determining the antibiotic of choice in combatting bacterial infections.

Acknowledgments

Valuable consultation by Dr. Allen Heim, Department of Microbiology, Schools of Medicine and Dentistry, Georgetown University, who was formerly directly associated with this project is gratefully acknowledged. Thanks are expressed for the intensive effort put on the project by Venton R. Harrison, now with the Walter Reed Army Medical Center. Also appreciated is the technical assistance of Louise Wilson and Mary Ragel.

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stitutes of Health, U. S. Public Health Service, Department of Health, Education, and Welfare, Washington, D. C.

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LONDON CONFERENCE

As indicated by the response to a questionnaire in July, there has been great interest in the forthcoming International Conference on Water Pollution Research to be held in London in September 1962.

The travel committee has learned that indications of interest in transportation can be handled as late as October 23. This is an extension of the questionnaire deadline of August 15.

If you have not mailed the questionnaire and consider yourself a possible attendee please complete the questionnaire and mail or direct a letter by October 23 to Thomas P. Quirk, Malcolm Pirnie Engineers, 25 W. 43rd St., New York 36.

THE ANAEROBIC CONTACT PROCESS IN PRACTICE

Edwin B. Fall, Jr., and L. S. Kraus

Findings of laboratory and pilot-scale studies of the anaerobic contact process indicate excellent removal of suspended solids and substantial removal of BOD by passing the sewage through a blanket of anaerobic sludge (1) (2) (3) (4).

The tank volume required is similar to the standard Imhoff tank and the efficiency of BOD and suspended solids removal is substantially higher. With these factors in mind it was thought desirable to modify the design of a proposed Imhoff tank for a subdivision in the Peoria area in such a manner that a full-scale anaerobic contact process experiment could be carried out.

Design Data

The total area of the subdivision tributary to the treatment plant is approximately 320 acres, and it is estimated that the ultimate development will have 900 homes. Approximately half of these are being served at the present time.

The houses average 3.63 persons and less than half of the homes are equipped with garbage grinders.

The treatment plant design is for 350 homes and consists of an anaerobic contact tank, followed by a dosing tank, trickling filter, and a small oxidation pond. The effluent is discharged to a creek which is relatively dry during the summer months. Recirculation between the influent end of the oxidation pond and the dosing tank was established during the spring and summer of 1959. Design factors are given in Table I.

Cost of Treatment Plant

The subdivider of the area served by the treatment plant is not only a land developer but also a home builder. His organization is such that the treatment plant construction fits well into his activities. The cost of the treatment plant includes all direct expenditures, but does not include supervision, overhead, and profit normal to construction contracts. Unit costs are given in Table II.

This cost for the design basis of 350 homes is equivalent to about $75 per home. On the basis of connected load during the summer of 1959 the cost is approximately $60 per home.

Objectives

It appeared from previous studies that it was possible to attain an 80-per cent removal of suspended solids and a 60-per cent removal of BOD. It further appeared that the rate of sludge formation was low and that little gas or scum was produced. These results are better than those normally produced by an Imhoff tank. The test data indicated that the removal of BOD was higher than that which could result from the gravity removal of suspended solids. This removal could be explained by biological action within the anaerobic sludge blanket.

The objectives of this study are:

1. What degree of treatment can be attained by the anaerobic contact proc-

Edwin B. Fall, Jr., is Chemist and L. S. Kraus is Manager of the Peoria Sanitary District, Peoria, Ill.

This paper was presented at the 33rd Annual Meeting of the Water Pollution Control Federation in Philadelphia, Pa., Oct. 2–6, 1960.

TABLE I.—Design Factors

Raw Sewage	
Average sewage flow (gpd/house)	250
Number of houses	350
Anaerobic Contact Tank	
Displacement period (hr)	26.3 @ 0.087 mgd
Trickling Filter	
Loading (lb/day/1,000 cu ft) at Imhoff tank efficiency	15
Oxidation Pond	
Area (acre)	0.37
Displacement period (day)	5.4 @ 0.087 mgd

TABLE II.—Unit Costs

Item	Cost
Anaerobic contact tank	$ 8,885
Dosing tank and trickling filter	12,961
Grading of site and oxidation pond	2,934
Engineering	1,240
Total	$26,020

ess as applied in the tank built in this subdivision?

2. What is the rate of sludge build-up, and the useful sludge storage capacity of the tank?

3. How is the tank efficiency affected by the depth of sludge?

4. What is the quality and quantity of sludge formed and the magnitude of the sludge disposal problem?

5. Is scum accumulation a problem?

6. What is the limiting rate of flow through the tank?

7. What is the effect of seasonal changes in temperature?

8. How much attention is needed to keep the tank in satisfactory operation?

The Anaerobic Contact Tank

The anaerobic contact tank was built as shown in Figure 1. The concrete structure is the same as that designed for an Imhoff tank to serve the sub-

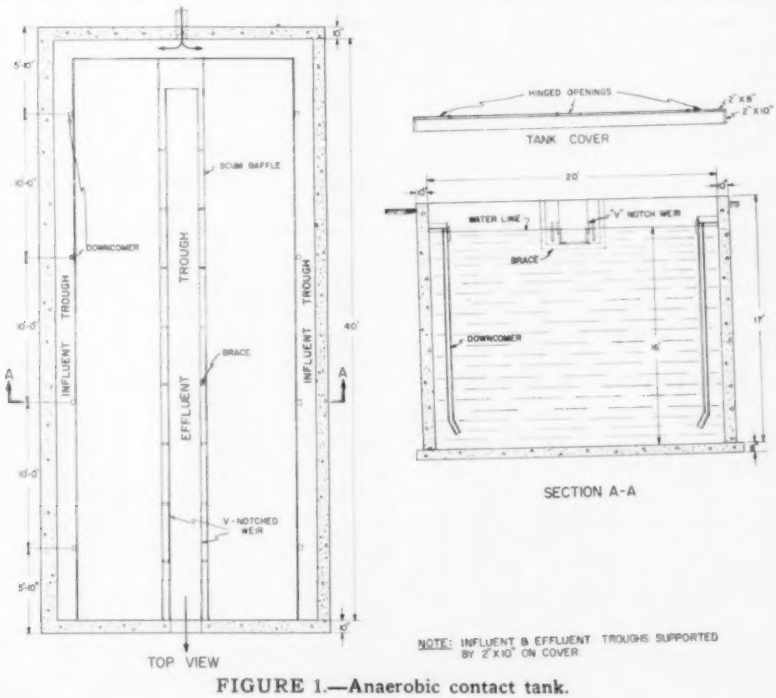

FIGURE 1.—Anaerobic contact tank.

TABLE III.—Variation of BOD of Contact Tank Effluent

Date	Time	BOD (mg/l)
9-25-58	12 N	170
	2 PM	205
	4 PM	195
	6 PM	180
	8 PM	200
	12 M	205
9-26-58	2 AM	205
	4 AM	205
	6 AM	200
	8 AM	190
Average		194

division. This differs from the pilot plant that had a conical tank with the sewage influent placed at the apex of the inverted cone and the effluent withdrawn at a point on the circular periphery of the base. These conditions could not be obtained in the rectangular tank used, but eight downcomers were spaced along both longitudinal walls with a velocity of 0.30 fps at design flow and the effluent was collected in a central longitudinal trough. Provisions were made for holding scum accumulations with baffles supported by the effluent trough.

All of the influent and effluent devices were constructed of untreated wood with galvanized nailing and were hung from the tank cover. The use of untreated wood under water was considered satisfactory for substantial life as experience with wood submerged in primary settling tanks for over 20 years indicates that only occasional renailing is required.

Sampling and Analyses

Raw sewage samples were collected by an automatic sampler, proportionate to flow and kept under refrigeration during the sampling period. The samples were picked up at the treatment plant three times each week and flow measurement readings were taken at the pumping station on the same days.

All other samples were grab samples taken one each two or three day period. A study of the variations in concentration shown in Table III indicates that these grab samples present an accurate picture of the operation.

Analytical data that were determined on the samples of influent and effluent from various points in the plant are biochemical oxygen demand, chemical oxygen demand, suspended solids, volatile suspended solids, pH, and occasional analyses for coliform and sulfides were made.

The sludge samples were taken from six locations longitudinally spaced at center points between the downcomers and transversely spaced midway between the influent and effluent conduit. Sludge samples were collected from varying depths and analyzed for total solids, volatile total solids, pH, and volatile acids.

Subdivision Sewage Treatment Problem

An unanticipated problem presented itself early in the study. In some cases, sewers in outlying subdivisions are not as carefully inspected as those within municipalities and the manner in which house connections are constructed is not always subject to the control and regulation of local municipalities. It was observed that excavations for new homes are frequently drained into the sewer system, and with each rain, substantial quantities of clay are washed into the sewers.

Since the development of such a subdivision extends over several years, this frequent washing of clay into the sewage treatment works materially affects the character of the sludge accumulated; thus, while in normal sewage treatment operation, sludges in the order of five to ten per cent total solids concentration are obtained, the sludges observed in this study vary between ten and thirty per cent total solids. This may be one of the important differences between the laboratory studies and the operation as carried out in the subdivision treatment plant.

Analysis of Data

An inspection of the average data collected over the 20 month period (Figure 2) reveals two broad characteristics of the plant.

1. During the winter months the anaerobic contact process functioned best and the trickling filter-pond combination operated at a lower efficiency.
2. During the summer the anaerobic contact tank functioned at a low BOD efficiency and the trickling filter-pond combination operated at a higher efficiency.

The plant produced an effluent that had satisfactory oxygen conditions and did not upset the branch of Big Hollow Creek into which it was discharged even during the dry summer of 1959 when there was no rain-water dilution. The creek showed no indication of decomposing sludge or algae.

Process Efficiency

The arithmetic means of the operational results during the test are 34 per cent BOD removal and 77 per cent suspended solids removal. The suspended solids removal is as anticipated from pilot-plant studies and substantially higher than that usually depended on from an Imhoff tank. The per cent removal of suspended solids was relatively constant and not seasonal.

The per cent removal of BOD was approximately the same as that expected in Imhoff tank operation. This was seasonal in this process and varied as an inverse function of the temperature. During the period of 47°F to 60°F tank temperatures the BOD removal averaged 42 per cent. During the summer when the tank temperatures were between 65°F and 71°F the average BOD removal was 14 per cent.

The cause of the low efficiency of BOD removal during the summer was that the sludge was undergoing an acid fermentation and the organic acids produced were carried out with the effluent.

For 10 months of operation the tank was serving more than the design capacity and the plant is now serving 36 per cent above design capacity with no loss of suspended solids efficiency. The retention period has been reduced to 13.4 hr.

Figure 3 shows the variation in monthly averages. Tank temperatures

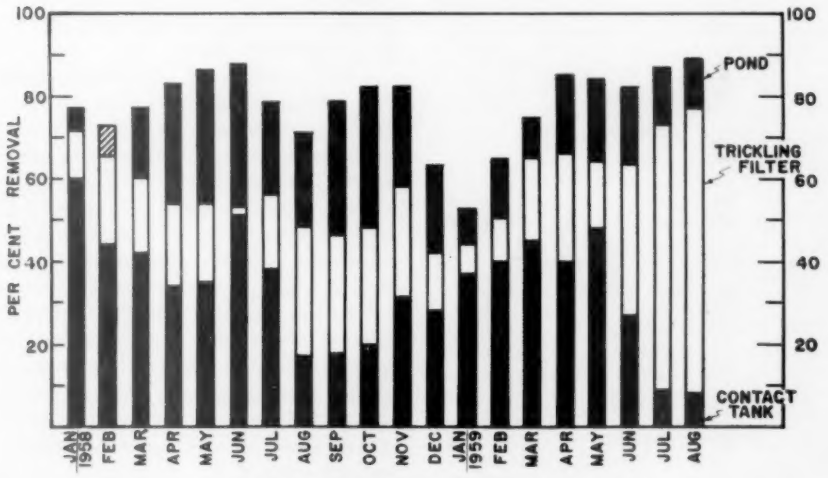

FIGURE 2.—BOD removal, per cent.

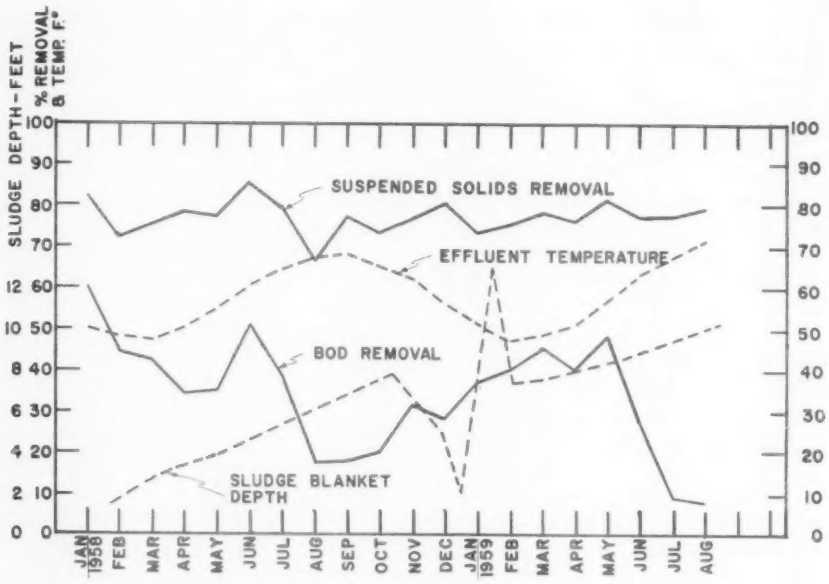

FIGURE 3.—BOD and suspended solids removal, per cent.

and sludge depths are given for comparison with the fluctuating efficiencies. It is apparent that the BOD removal is adversely affected as the depth and temperature of the sludge increase. The temperature of the sludge was observed to be within 3°F of the effluent temperature.

TABLE IV.—Anaerobic Contact Tank Averages

Raw Sewage	
Factors	
(gpd/cap)	86
BOD (lb/day/cap)	0.16
SS (lb/day/cap)	0.26
Concentration	
BOD (mg/l)	242
COD (mg/l)	528
SS (mg/l)	368
VSS (mg/l)	250
Contact Tank Effluent	
Retention time (hr)	22.4
BOD (mg/l)	160
COD (mg/l)	286
SS (mg/l)	76
VSS (mg/l)	65
Contact Tank Efficiency	
BOD (per cent)	33.6
COD (per cent)	45.8
SS (per cent)	76.8
VSS (per cent)	73.1

From the data presented in Table IV it is obvious that while the removal of suspended solids is quite good, additional treatment of the effluent is needed to avoid pollution of the receiving stream.

During this study no floating material was removed from the tank surface, and at no time was a scum layer in evidence. A small amount of gasification was observed.

Thirteen samples of contact tank effluent were taken for sulfide determinations. These averaged 0.4 mg/l as H_2S and varied between 0.0 and 0.8 which was insufficient to cause an odor at the filter. The water supply contains 40 to 60 mg/l of sulfates.

The maximum rate of flow during the period reduced the monthly average displacement time to 13.4 hr without any loss in efficiency. The detention time will continue to be reduced

TABLE V.—Sludge Analyses

Sludge Depth (ft)	Total Solids (%)	Volatile Total Solids (%)	pH	Volatile Acids (mg/l)
1	23.1	52.8	5.8	5,300
2	34.7	29.3	6.1	2,900
4	17.9	45.0	6.5	2,500
6	18.0	44.8	6.6	2,500
8	13.7	44.1	6.9	500

until velocities are such as to materially increase the effluent suspended solids.

Sludge Data

Table V represents sludge analyses with 12 ft of sludge in the 16 ft water depth tank. The sludge was allowed to accumulate to this depth to determine what maximum operating level would be consistent with good suspended solids removal. It appears that a 10 ft depth should be the maximum operating sludge level. A similarly designed Imhoff tank would have a maximum allowable sludge depth of about 8 ft.

Analyses of Table IV present a nontypical situation at the one- and two-ft levels but this condition has been repeatedly observed since the sludge layer reached the six foot depth. The high solids concentration is partly due to the clay and silt washed into the plant.

The rate of sludge build-up was estimated for two periods: Mar. 6, 1958 to Oct. 24, 1958, and Feb. 19, 1959 to Nov. 11, 1959. The rate of sludge accumulation was 0.50 and 0.27 cu ft per capita per month, respectively. During the period Jan. 20, 1959 to Nov. 11, 1959, the dry solids accumulation in the sludge blanket amounted to 4.8 lb per capita per month.

If the sludge depth is allowed to vary between 3 and 10 feet, the storage capacity in this tank would be 16.3 months at design load of 1,270 people. It is apparent that the sludge-holding capacity of the tank is much greater than that required by the design data.

The acid fermentation in the sludge presented two problems: (1) volatile acids in the effluent and (2) pig-pen odor in the sludge. The first effect was to decrease BOD removal and at times produce a slight odor in the effluent. The second would result in an odor problem if the sludge was dried and applied untreated on open beds. Attempts made to stop the acid fermentation by liming, seeding with well-digested sludge, and removing most of the acid sludge and seeding with a large quantity of digested sludge, were unsuccessful.

An analysis of the solids in the anaerobic contact tank for the 10 month period is given in Table VI.

It appears that a substantial quantity of sludge is decomposed. By coincidence the volatile matter lost is 62.5 per cent, a quantity commonly used in computations for the methane fermentation of fresh solids.

Summary

The anaerobic contact process as evaluated by this study has the following characteristics:

1. The average suspended solids removal is 77 per cent.

2. The average BOD removal is 34 per cent.

3. The mean rate of sludge accumulation is about 0.4 cu ft per capita per month, and the effective storage depth is 10 ft in a 16-ft water-depth tank.

TABLE VI.—Solids Retained in Contact Tank Jan. 20, 1959 to Nov. 11, 1959

Item	Total Solids (lb)	Volatile Total Solids (lb)
Sludge in tank Nov. 11	103,300	44,200
Sludge in tank Jan. 20	30,500	16,000
Sludge accumulated	72,800	28,200
SS removed	116,700	75,200
Solids liquefied, dissolved, or gasified	43,900	47,000

TABLE VII.—Trickling Filter Data

Volume of filter in service (cu ft)	7,800
BOD in influent (mg/l)	160
BOD loading (lb/1,000 cu ft)	16.2
Volumetric loading (mgd/acre)	3.6
BOD in effluent (mg/l)*	114
Coliform (MPN)	2.8×10^6
Removal BOD (per cent)	28.8
Removal of coliform (per cent)	28.2

* Unsettled effluent.

4. The efficiency of BOD removal is adversely affected by increasing the depth of sludge.

5. The sludge formed has a disagreeable odor which can be removed by liming.

6. Scum is no problem.

7. The average retention period, consistent with good suspended solids removal, is below 13 hr.

8. The BOD removal is adversely affected by summer temperatures, but the suspended solids removal remains approximately constant.

9. Very little attention is required for operation.

Advantages of Anaerobic Contact Process

1. Better suspended solids removal in the anaerobic contact process, 77 per cent vs. Imhoff tanks, 60 per cent.

2. No scum problem in anaerobic contact tank.

3. No foaming problem in the anaerobic contact process.

4. Greater sludge storage capacity.

5. Greater sewage flow capacity.

6. Uniform distribution of sludge.

7. Lower construction cost.

8. Less operating attention required.

Disadvantage of Anaerobic Contact Process

Sludge requires treatment before drying on open beds.

Trickling Filter Data

The performance of the trickling filter was disappointing. During the period Jan. 1958 through Feb. 1959, when no recirculation was used, the average loading was 16.2 lb/1,000 cu ft. This should have resulted in a BOD removal in the order of 80 per cent instead of the low percentage obtained.

Recycling from the influent end of the oxidation pond was started in Mar. 1959. During the period Sept. 23 through Nov. 1, 1959, the BOD concentration of the recycled liquid was 55 mg/l and that of the oxidation pond effluent was 57 mg/l.

Oxidation Pond Data

During the period Jan. 1958 through Feb. 1959, the oxidation pond removed a substantial part of the BOD. The pond is small, 0.37 acres, with an average depth of 3.9 ft.

The oxidation pond was used to eliminate a final settling tank and waste sludge pump. It not only was cheaper but proved effective in stabilizing the effluent.

The BOD loading on the pond was 235 lb/day/acre. The removal from an influent of 114 mg/l to an effluent of 53 mg/l was 53 per cent.

During the study, 24,000 lb of dry SS were removed in the pond. This was insufficient to produce an appreciable sludge layer in the pond.

The treatment for the test period produced an oxidation pond effluent of 53 mg/l BOD and 70 mg/l suspended solids. This represents an over-all removal of 78 per cent of the BOD and 81 per cent of the suspended solids. Figure 2 indicates the average BOD removal during the study. The coliform organisms were substantially reduced in the pond with ten sets of data indicating a 94 per cent reduction.

Summary

1. The trickling filter did not perform to expectations and resulted in lower BOD removal than anticipated.

2. The oxidation pond, though overloaded, effected a substantial BOD removal and produced an effluent that

was satisfactory for the conditions normal to Big Hollow Creek.

Acknowledgments

This full-scale test was discussed with C. W. Klassen, Richard S. Nelle, and John J. Forneris, of the Illinois Sanitary Water Board, and was undertaken with their cooperation. The study was assisted by the U. S. Public Health Service under Public Law No. 152.

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DISCUSSION

James B. Coulter and M. B. Ettinger

Early Investigations

As early as 1910, Winslow and Phelps (1) were investigating what they called a "biolytic tank." Sewage was fed into the bottom of an inverted conical tank and flowed upward through a blanket of digesting sludge. They found that the removal of suspended solids was as good as that obtained in a septic tank and that the liquefaction of deposited solids was distinctly better.

A few years later, Phelps (2) investigated a modification of the biolytic tank. He constructed a septic tank with an over-and-under baffle arrangement so that sewage in passing from one compartment to the next was forced into the sludge zone.

From their observations they concluded that the biolytic tank was unsatisfactory. A comparison of the work of Phelps with that of Winslow and Phelps indicates that perhaps the baffle arrangement, rather than the principle itself, was responsible for the failure. It is doubtful that the baffles forced all of the incoming sewage into contact with the accumulated sludge.

In recent years Schroepfer *et al.* (3) have demonstrated a good removal of BOD and suspended solids with the anaerobic contact process. In their work with domestic sewage as well as packing house and other industrial wastes, they utilized the same principles as those observed in the conventional activated sludge process.

The first experiments with this principle at the Sanitary Engineering Center were conducted on a bench-scale model in the laboratory. Two units, a

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This discussion was presented at the 33rd Annual Meeting of the Water Pollution Control Federation in Philadelphia, Pa., Oct. 2–6, 1960.

TABLE I.—Comparative Loading and Performance of Anaerobic Contact Tanks

Item	Loveland Pilot Plant	Rolling Acres Subdivision
(a) Loading		
Volume raw sewage (gpd)	1,650	102,800
Displacement time (hr)	18	22
Rise rate (fpd)	3.5	28
Areal loading (gpd/sq ft)	26	206
Velocity in downcomers (fpm)	7	36
COD (lb/day)	9.6	736
COD (lb/day/1,000 cu ft)	58	58
BOD (lb/day)	3.4	320
BOD (lb/day/1,000 cu ft)	20	25
SS (lb/day)	5.9	600
SS (lb/day/1,000 cu ft)	30	47
(b) Performance		
Removals (per cent)		
COD	62	46
BOD	67	34
SS	83	77
Effluent quality (mg/l)		
COD	263	286
BOD	80	160
SS	72	76

contact chamber similar to the biolytic tank and an upflow rock filter were used. Highly satisfactory performance was observed both at room temperature and at 4°C in a constant temperature box. A large-scale pilot plant was constructed at Loveland, Ohio, as a result of these encouraging results. Because of the production of hydrogen sulfide in the up-flow rock filter the effluent was deemed unsuitable for disposal without benefit of substantial dilution water but good removals of suspended solids and chemical oxygen demand were observed. Furthermore, the major SS and COD removal was accomplished in the contact chamber with the production of a negligible amount of hydrogen sulfide.

In discussions with the authors the possibilities for primary treatment were recognized and suggestions were made for substitution of the contact process for the Imhoff tank unit of a plant under design for a subdivision in Peoria, Ill. The substitution was made and the plant had performed satisfactorily for 20 months. Loading and performance of the Peoria plant are compared in Table I with that observed at the Loveland pilot plant.

Contact Tank

Large amounts of silt and clay in the influent of the Peoria plant could have been responsible for the good removal of suspended solids. On occasion the soil particles undoubtedly added a readily separable fraction of suspended solids in the plant influent and the weighting factor of these solids could have been beneficial in sedimentation of normal sewage organic solids, yet the removal of SS was also good during low silt conditions. At Loveland where little grit or mud entered the tank the pilot plant was highly efficient in the removal of suspended solids. These observations lead to the conclusions that the SEC anaerobic contact chamber is an excellent device for removing suspended solids.

A puzzling aspect of the pilot-plant test at Loveland was the high removal of BOD in the absence of methane production. Our present understanding is that under anaerobic conditions a significant BOD reduction must be accompanied by the production of methane gas. A more logical pattern of behavior was observed at Peoria where sludge was fermented with the production of volatile acids which in turn produced BOD in the effluent. The effectiveness of the fermentation was demonstrated by a 62 per cent reduction in sludge volatile material without production of significant quantities of gas. This reduction is about the same as could be expected from methane fermentation of primary sludge in a digester. The high concentration of volatile acids in the sludge, and a low removal of BOD in relation to the removal of suspended solids indicates that deposited matter was being liquefied and washed from the tank by the effluent. The conversion of suspended solids to dissolved solids in itself did not reduce the BOD sufficiently, but the dissolved solids were subsequently

treated in the aerobic portion of the scheme.

Constant and better elutriation of the lighter sludge at Loveland prevented a buildup of volatile acids such as that observed at Peoria. The abnormal solids content of the sludge in the Peoria plant probably resulted in marginal elutriation. Without continual washing of the sludge, volatile acids should accumulate and performance might approach a pattern of seasonal behavior similar to that of a septic tank. In this respect, the trial at Peoria provided an extreme test. It is doubtful that a denser sludge will ever be formed. Thus, the quality of the effluent is representative of extreme conditions that may develop when the sludge is not continually washed.

Normally the processes of sedimentation and sludge digestion are considered to be incompatible. For instance, septic tank gasification causes solids to float, scum blankets to form, and occasionally the entire contents of a tank to "turn over." The conflicting nature of the two processes led to the development of separate sedimentation and sludge digestion methods. These undesirable characteristics were not observed in the SEC anaerobic contact process. Suspended solids removal at Peoria was consistently good while sludge was accumulating at the rate of 4.8 cu ft per person per year. It is concluded that 10 ft of sludge can be stored in a 16 ft deep tank without interfering with sedimentation.

Even though the contact process could be substituted for an Imhoff tank to provide primary treatment, the two devices operate on different principles. The Imhoff tank separates fresh sewage from digesting sludge while the contact process introduces fresh sewage directly into the sludge blanket. Retention time in the flow-through chamber of an Imhoff tank is kept low to prevent sewage from becoming anaerobic, but in the contact process liquid is retained as long as possible and an anaerobic effluent is deliberately produced. In Imhoff tanks, sludge solids are stabilized through anaerobic digestion with the production of methane gas while in the contact process the sludge is concentrated and stabilized by liquefaction and elutriation.

Pond and Filter

Although the oxidation pond was intended for secondary settling with some incidental polishing of the filter effluent, it did a remarkable job of BOD removal. A pond could be expected to treat 35 to 50 lb/day/acre of BOD yet it accepted 235 lb without producing nuisance conditions. It is hard to believe that aerobic conditions could be maintained winter and summer for two years at that loading of anaerobic sewage.

The performance of the trickling filter was especially disappointing in view of the fact that the filter and dosing tank accounted for approximately 50 per cent of the total cost of the treatment plant.

However, one should not lose sight of the fact that the trickling filter was a supplementary source of oxygen. Perhaps the oxidation pond would have gone anaerobic without the preconditioning of the anaerobic tank effluent and the continual supply of oxygen provided by the trickling filter.

Costs

The Rolling Acres test plant was constructed at a cost per home less than that normally paid at housing subdivisions. Assuming that 450 homes is a reasonable design load for this plant, the actual cost is approximately $60 per home. Allowing a generous markup of 50 per cent for the fees chargeable to supervision, profit, and overhead, the initial cost is still only $90 per home. First costs can be misleading unless allowances are made for land occupied or rendered undesirable by the plant and for the maintenance

and operating charges. A plant similar to that at Peoria could be constructed on less than an acre of land. Actual operation of the plant is simple and maintenance is nominal; however, pumping and disposing of wet sludge is a significant expense.

The treatment plant management contracted to have 5,600 cu ft of sludge pumped from the tank and trucked to a disposal point in the Greater Peoria sewerage system for $1,300, a unit cost of $0.23 per cu ft. The rate of accumulation is 0.4 cu ft per person per month, or with an average occupancy of 3.6 persons, the annual accumulation will be 17.3 cu ft per home. The cost of removing sludge once a year is $3.98 per home.

The sewage treatment test plant at the Rolling Acres subdivision is an interim arrangement to serve until a trunk sewer is constructed. The sewer is expected in five years, but allowing another five years for unforeseen delays, the plant should be designed for ten years. Sludge removal will be a periodic cost during the ten-year period. If this recurring cost is put on a present value basis it can be added to the cost of the plant. The total cost of this scheme may then be compared with the cost of other arrangements for treating the sewage and disposing of the sludge. In this case where payments are anticipated annually the present value of the cost of removing sludge is equal to the annual cost multiplied by 7.36, the annuity factor for ten years at six per cent.

From this calculation the cost of removing sludge during the next ten years is accounted for by adding $29 per home to the first cost of the treatment plant. Thus a capital improvement to the treatment plant at Rolling Acres to eliminate the necessity to haul sludge would be justified at a cost less than $29 per home. Stated another way, the present value of the cost to construct the plant and remove sludge at periodic intervals is $119 per home. An alternate treatment plant whose only advantage over this plant is elimination of sludge hauling is not justified if its cost is greater than $119 per home.

It can be argued that the foregoing calculations ignore the cost of treating the sludge at the Greater Peoria Sanitary District's plant. The argument is valid and that cost should be included by treating it in the same manner as the sludge hauling cost. The example calculations demonstrate a method for placing all costs on a present value basis.

Economic analysis can be applied to a decision between interim sewerage treatment schemes with widely differing first costs and maintenance and operating costs. After it is determined that the various schemes will produce the desired quality of effluents, their individual first costs and recurring operational costs can be summed as present values. Ordinarily the plant with the lowest cost would be selected. The essential elements for the analysis are that alternate schemes will produce satisfactory effluent, initial costs and subsequent operational costs can be estimated, salvage values and transition costs can be estimated, and the time of service for the scheme can be determined. For treatment plants intended to serve for a period of only a few years, relatively high operational costs can be borne in return for a disproportionate decrease in initial cost. On the other hand, for a plant designed to serve for a long time, a high first cost and a low annual operating cost might be more desirable.

Summary

The combination of the anaerobic contact process followed by aerobic treatment provided treatment that was highly satisfactory for the critical effluent discharge condition represented by intermittent flow in Big Hollow Creek. During the winter when the efficiency of the aerobic portion was

reduced, the efficiency of anaerobic contact was at its highest. In the critical summer months, the performance of the contact tank was below par but the improvement in the pond and filter was more than adequate to keep the characteristics of the effluent within allowable limits.

The test plant demonstrates that the SEC anaerobic process has merit as an economical device for primary treatment of sewage. The contact tank removed a large fraction of the suspended solids and the BOD removal was satisfactory. Sludge was concentrated and stored in the tank for a long period of time without interfering with sedimentation. The process demonstrated a broad operating range which is a highly desirable feature for plants that have a minimum of supervision. Cost analysis indicates that this type plant will be highly competitive in many situations where interim sewage treatment is needed.

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GRADUATES FARE WELL IN 1961

In spite of the recent economic recession 1961 engineering graduates' employment has been excellent. As of May 19, 84.4 per cent of the engineering graduates had either secured jobs, decided on post-graduate studies, had been committed to military service, or had other definite plans. By June 15, this figure was 91.8 per cent.

The comparative figures for 1959 and 1960, as of May 19, were 83.6 and 81.5 per cent, respectively.

This information was the result of surveys made by the Engineering Manpower Commission of Engineers Joint Council.

STEEL MILL SLUDGE RECOVERY

Richard D. Hoak

Three kinds of sludge are peculiar to the steel industry: flue dust, mill scale, and neutralized pickle liquor. Sludges from water treatment and boiler blowdown occur also, but these are relatively small in amount and are common to industry in general.

Flue Dust

Pig iron is made in blast furnaces. These are tall, cylindrical stacks lined with firebrick. Iron ore, flux, and coke are fed to the top of the furnace through a double bell and hopper which serves the dual functions of distributing the charge uniformly in the stack, and preventing emission of dust and gas during charging. Preheated air is blown into the bottom of the stack under pressure to furnish the heat and oxygen needed to smelt the ore. This process continuously reduces iron ore to molten iron which collects on a hearth at the base of the furnace. The metal is periodically tapped into ladles for transfer to steel-making furnaces, foundries, and other operations.

Air is blown into blast furnaces at a rate of 40,000 to 100,000 cfm, and each cubic foot of air produces 1.35 cu ft of exit gas from reactions in the furnace. The velocity of the gas is thus very high as it passes through the voids in the charge. Small particles of ore, flux, and coke are carried out of the furnace in the offgas, and this suspended material is called flue dust.

The top of the blast furnace is equipped with two or more large pipes known as "downcomers" to carry the gas to dust removal equipment. The downcomers have bleeder valves to protect the furnace against pressure surges. These valves open automatically when the gas pressure exceeds a safe limit, and discharge the gas to the atmosphere. Blast furnace performance can be very inconsistent; in spite of modern controls the furnace often behaves in unpredictable ways. One of the serious difficulties in furnace operation is the tendency for the charge to form a bridge in the stack. When this happens the stock settles below the bridge and the gas pressure increases. When the bridge opens or slips a large volume of gas passes rapidly to the rest of the furnace system and takes with it great quantities of dust and even large pieces of the charge.

Gas leaving the furnace will carry 10 to 15 grains (0.0014 to 0.0021 lb) of dust per cubic foot, on an average. The dust consists of particles of ore, coke, and limestone. When a furnace is operating smoothly the particles will range in size from a quarter inch to a few millionths of an inch in diameter. The gas passes first to a dry dustcatcher, which is a cylindrical steel shell 20 to 40 ft in diameter, with cylindrical top and bottom. Dustcatchers remove 60 to 80 per cent of the dust in the gas. The range of size of particles in the gas leaving a dustcatcher is given in Table I, and the chemical composition of the dust is shown in Table II.

Blast furnace gas is a low-grade fuel (about 90 Btu/cu ft), but it must be cleaned before it can be burned in equipment. The gas leaving the dustcatcher passes to a water scrubber which removes 90 to 95 per cent of the dust remaining. A secondary cleaner

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is employed where exceptionally clean gas is required. Both electrostatic precipitators and disintegrators are used for the secondary stage; these remove 90 to 95 per cent of the dust leaving the primary scrubber. Thus these three operations remove substantially all of the dust from the gas.

The volume of water needed to wash the gas ranges from 10 to 40 gal/1,000 cu ft of gas. Water used in primary scrubbers may be 500 to 5,600 gpm, because the furnaces produce 50,000 to 140,000 cfm of gas. Water is conserved in furnace operation through use of the condenser water to cool the furnace shell and then to supply the

TABLE I.—Particle Size in Dry Dust Leaving a Dustcatcher

Screen Opening (in.)	Per Cent
0.0328	2.5–20.2
0.0232	3.9–10.6
0.0164	7.0–11.7
0.0116	10.7–12.4
0.0082	10.0–15.0
0.0058	10.2–16.8
0.0041	7.7–12.5
0.0029	5.3– 8.8
>0.0029	15.4–22.6

gas washers. Water leaving the washers may contain 50 to more than 200 grains of dust/gal (850 to 3,500 mg/l).

Dirty water from the washers is clarified in various ways before discharge to a sewer or to a river. Formerly the general practice was to store the water in lagoons or sumps, with provision for effluent discharge. The increasing values of land at most steel mills has been forcing abandonment of this method in favor of mechanically-cleaned clarifiers which occupy much less area for a given capacity. The underflow from clarifiers is normally filtered on conventional vacuum filters. The filter cake is combined with an appropriate amount of coke breeze and sintered to hard lumps that are returned to the blast furnace for smelting.

TABLE II.—Chemical Composition of Dry Dust

Component	Per Cent (Dry Basis)
Iron, as Fe	36.5–50.3
Phosphorus, as P	0.1– 0.2
Manganese, as Mn	0.5– 0.9
Silica, as SiO_2	8.9–13.4
Alumina, as Al_2O_3	2.2– 5.3
Lime, as CaO	3.8– 4.5
Magnesia, as MgO	0.9– 1.6
Sulfur, as S	0.2– 0.4
Carbon, as C	3.7–13.9

Flue dust is not a waste product. It is separated from wash water as completely as possible for reprocessing. Several years ago, however, a question was raised about the over-all efficiency of dust recovery in the Ohio Valley and a survey was made by all the steel companies in that area. This survey provided information that had not been available on a comprehensive basis.

The concentration of suspended solids in gas-washer water fluctuates over a wide range as a function of normal variations in furnace operation. In addition, the amount of dust produced from furnace to furnace varies with the chemical and physical properties of the furnace charge. Thus it was necessary to develop a sampling procedure that would yield representative data. This was done by making an intensive study at a typical clarifier installation. Samples of influent and effluent were collected at 20-min intervals for two hours on each of 23 days over a period of two months and analyzed individually for total suspended and nonsettleable solids. The results were compared with data from hourly samples collected over a 24-hr period and analyzed individually, and with the re-

TABLE III.—Median Values in Dust Recovery Practice

Total dust made (lb/ton iron)	202.1
Wet dust made (lb/ton iron)	35.0
Dry dustcatcher efficiency (%)	69.0
Wet dust recovery efficiency (%)	93.5
Solids in washer water (mg/l)	2,070
Wet dust discharged (lb/ton iron)	3.7
Dust in effluent (mg/l)	167

sults from 15-min and 60-min composite samples taken over the same period. Statistical analysis of all data showed that the average of individual samples over a 24-hr period was within the confidence interval of samples from the two-month study. Also, data for the composited samples did not deviate enough from the long-term averages to invalidate this method of sample collection. The survey was therefore based on hourly samples composited over 24-hr periods.

This study disclosed that the 79 furnaces in operation produced an average of 8,033 tons of dust/day, of which 7,550 tons or 94 per cent was recovered. Median values for some of the parameters evaluated are given in Table III.

Mill Scale

The manufacture of various steel products entails rolling hot metal into desired shapes. Hot steel oxidizes rapidly in air, and the film of oxide scale thus formed must be removed from the metal just before it is rolled. This is generally done by directing a water spray onto the metal surface immediately ahead of the rolls. Most of the scale drops into a flume and is carried by a stream of water to a scale pit. The volume of water used in this operation varies with the stock being rolled, but it will usually fall in the range of 2,000 to 4,000 gpm.

Mill scale may contain upward of 70 per cent iron as a mixed oxide and is equivalent to very high grade iron ore. It is thus a valuable by-product that is recovered for reworking in blast furnaces or open hearths. Scale particles range in size from an inch or more in breadth to a micron (0.00004 in.) or less. Some 80 to 90 per cent of the scale particles settle rapidly from water, and recovery of this portion of the total is not difficult. The finely-divided particles settle quite slowly and cannot be recovered efficiently in typical scale pits. These pits are usually deep, rectangular basins, but they vary widely in design. Most of them were installed many years ago, and their sizes and shapes were often dictated by the space available. Scale is periodically dredged from the pits and storaged until it can be charged to the furnaces.

The success of the flue dust survey led to a proposal that a similar study be made of mill scale recovery. This turned out to be a much more difficult problem. Although the amount of suspended solids in gas-washer water fluctuates widely, it is possible to determine average concentrations by a statistically sound sampling program. This permits calculation of recovery efficiencies by means of material balances. Flue dust particles are small enough to remain in suspension where there is only moderate turbulence. This is not true of mill scale. The heavy pieces of scale slide along the bottom of the flume that carries the scale away from the rolling mill and only the finer particles are suspended in the water. The non-uniform distribution of scale in the flume water makes it impossible to collect representative samples, and a material balance cannot be made directly.

The water in conventional scale pits is very turbulent, and theoretical retention times are quite short. For example, a typical pit ($50 \times 8 \times 10$ ft deep) has a calculated retention time of 7.2 min. It would not be expected that much finely-divided material would deposit in a scale pit under such conditions, and it is remarkable that roughly 90 per cent of the fine particles settle out.

Relatively coarse scale settles so rapidly that it constitutes no recovery problem. Thus the efficiency of a scale pit should be based on the effectiveness with which it removes the fine material that settles slowly. A method for evaluating pit performance was developed by measuring the settling rate of influent solids and relating this to the concentration of suspended matter in the pit effluent. Influent samples

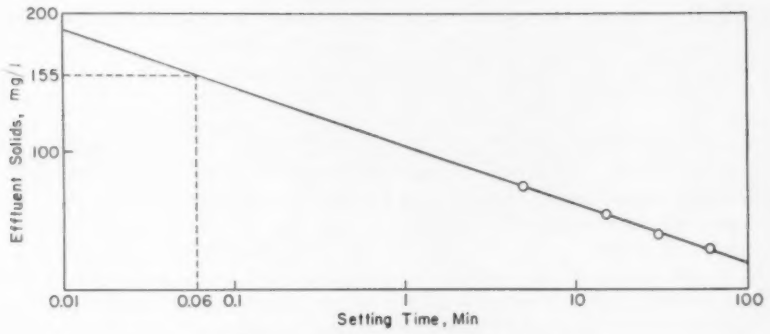

FIGURE 1.—Scale pit settling values.

(300 ml) were taken every 20 min for 8 hr and composited. Effluent samples were similarly composited. Settling rates were measured on influent composites at 5, 15, 30, and 60 min. Total suspended solids were determined on effluent composites. The rate data were plotted on semi-log paper and the best straight line was extended through the points toward an ordinate which represented the concentration of solids in the pit effluent. A time-value could then be read on the abscissa below the intercept of the effluent concentration with the rate curve, as shown in Figure 1. This value represents the equivalent quiescent settling time of the suspension in the pit. The typical pit cited above was used for the example given in the figure. The concentration of suspended solids in the influent was 1,120 mg/l, in the effluent 155 mg/l. The figure shows that the initial concentration would have fallen to 155 mg/l if the suspension had settled under quiescent conditions for 0.06 min. Extrapolation of laboratory data over the range of Figure 1 would ordinarily be a highly questionable procedure, but studies were made on 10 sedimentation units of various shapes and sizes with reasonably consistent results. The concept of equivalent quiescent settling time is an obvious abstraction, and to avoid confusion this parameter has been termed the "Sedimentation Index" because it is a useful tool for evaluating pit performance.

Analysis of a large amount of laboratory and field data led to the following empirical equation for rectangular pits with inlet at one end and outlet at the other, and for water at normal temperature.

$$SI = 2.43\, L^{1.33}\, W^{2}\, D^{3.33} \times (2D + W)/Q^{3.67}$$

Where

SI = Sedimentation Index (min)

L = Effective pit length (ft)

W = Effective pit width (ft)

D = Effective pit depth (ft)

Q = Influent flow (cfm)

Applying this equation to the basin under discussion ($L = 50$, $W = 10$, $D = 8$, $Q = 557$) the Sedimentation Index would be 0.096, corresponding to 147 mg/l as compared with 155 mg/l from direct measurement. Various hypothetical cases can be selected to illustrate the effect of the several factors. If, for example, the flow through the pit were halved for the same amount of entering scale, the Sedimentation Index would be 1.24, corresponding to an effluent concentration of 198 mg/l. (This computation requires a new settling-rate curve.) It might seem that performance becomes poorer at the

lower flow rate, but the actual scale loss at the higher rate would be 3.7 tons/day whereas it would be 2.5 tons/day at the lower rate. Increasing the pit length to 75 and 100 ft would yield effluent concentrations of 137 and 130 mg/l, respectively. Making the pit substantially longer would thus appear to improve performance only slightly. Changing the depth of the pit has a much greater effect. If the depth were reduced to 6 and 4 feet the Sedimentation Indexes would become 0.0315 and 0.0067, corresponding respectively to 168 and 198 mg/l for the effluent. This illustrates the decrease in performance that results from a buildup of scale in a pit and indicates the desirability of frequent cleaning.

The empirical equation that evolved from this study has been an aid in understanding the behavior of finely-divided, high-density particles in a turbulent medium. It would be desirable to provide a theoretical basis for the equation in order to arrive at a generalized expression for basin performance. A model-study has therefore been undertaken to develop fundamental equations for the purpose. The investigation is still in progress, but the preliminary equations yield results consistent with those from the empirical equation. It is anticipated that this project will provide a method for designing scale pits with higher efficiencies than those now in service.

Pickle Liquor

The thin film of oxide scale that forms on steel surfaces must be removed prior to further processing, such as galvanizing, tin-plating, and the like. This is usually accomplished by immersing the metal in a bath of hot, dilute sulfuric acid. Reaction of the acid with scale and base metal forms ferrous sulfate and gradually reduces the strength of the bath. The spent liquor from this operation cannot be discharged to streams or sewers without treatment.

Spent pickle liquor is customarily neutralized with lime. The resultant slurry of ferrous hydrate is usually stored in lagoons. Provision of devices for recovering and using the supernatant liquor is rarely worth the cost, because the slurry volume is often as large as the original mixture and the solids do not settle well. An exception occurs where rinse water and strong liquor are combined prior to neutralization. The supernatant that separates in such cases can provide a source of clear water for low-level cooling or other purposes. Sludge from pickle liquor neutralization remains plastic for an almost indefinite time, and no practical use has been found for it. Many years ago a process was developed for manufacturing wallboard from the sludge. The product had desirable properties as a construction material but it could not compete on a price basis with other wallboards on the market.

A neutralization process that avoids the necessity for lagooning this sludge is in commercial use. Streams of pickle liquor and lime slurry in proper proportion are combined in a reactor equipped with an efficient agitator and aerator. Partial oxidation of the ferrous hydrate yields a slurry that can be vacuum-filtered to produce a cake containing about 60 per cent dry solids. This material can be trucked to a dump. The process also makes more efficient use of the basicity of the lime than is possible in conventional neutralization plants. A portion of the filtrate is used to make fresh lime slurry and the remainder is discharged.

Summary

Flue dust and mill scale are valuable by-products of iron and steel manufacture that are recovered as completely as possible for reworking. A research

project has been undertaken to improve the efficiency of recovery of these materials. Neutralization of spent pickle liquor produces a sludge that is not only worthless but which is expensive to store at a final disposal site.

Acknowledgment

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MEETINGS OF INTEREST

Oct. 16–20	**American Society of Civil Engineers,** Annual Convention, Hotel Statler, New York. W. W. Wisely, ASCE, 33 West 39th St., New York 18.
Oct. 16–20	**National Safety Council Annual Meeting,** Chicago, Ill. National Safety Council, 425 North Michigan Ave., Chicago 11, Ill.
Oct. 17–Nov. 9	**Sewage Disposal and Plant Operation** (Short Course), Rutgers University, New Brunswick, N. J. Dean, College of Engineering, Rutgers University, New Brunswick, N. J.
Oct. 19–21	**National Society of Professional Engineers,** Hotel Roanoke, Roanoke, Va. NSPE, 2029 K St., N.W., Washington 6, D. C.
Oct. 23–25	**International Water Conference of the Engineers' Society of Western Pennsylvania,** Penn-Sheraton Hotel, Pittsburgh, Pa.
Oct. 23–28	**First Inter-American Congress of Chemical Engineering,** San Juan, P. R. Secretary, Institute of Chemical Engineers of Puerto Rico, Box 47, Rio Piedras Sta., P. R.
Oct. 31–Nov. 3	**Second Effluent and Water Treatment Exhibit and Convention,** Seymour Hall, London, England. Thunderbird Enterprises Ltd., 140 Cromwell Rd., London S.W. 7.
Nov. 4	**Pittsburgh Sanitary Engineering Conference,** Graduate School of Public Health, University of Pittsburgh, Pittsburgh, Pa. Dr. Eugene Weisberg, 1626 Forbes Ave., Pittsburgh 29, Pa.
Nov. 13–17	**American Public Health Association,** Cobo Hall, Detroit, Mich. APHA, 1790 Broadway, New York 19.
Nov. 21	**11th Semiannual Meeting and Midyear Conference of the Manufacturing Chemists Assn., Inc.,** New York, N. Y. MCA, 1825 Connecticut Ave., N.W., Washington 9, D. C.
Nov. 26–Dec. 1	**American Society of Mechanical Engineers,** Winter Annual Meeting, Statler Hilton Hotel, New York. ASME, 345 East 47th St., New York 17.
Dec. 3–6	**American Institute of Chemical Engineers,** Hotel Commodore, New York. F. J. Van Antwerpen, 25 West 45th St., New York 36.
Dec. 26–31	**American Association for the Advancement of Science,** Denver, Colo.

REMOVAL OF ENTEROVIRUSES FROM SEWAGE BY ACTIVATED SLUDGE

Sally Kelly, Wallace W. Sanderson, and Carol Neidl

In a field study of the effects of sewage treatment, the activated sludge process was most consistent in removing enteroviruses from sewage (1). By "removal" is meant non-detection of virus. Primary and, occasionally, secondary treatment was ineffective. Bloom *et al.* (2) also cite a low frequency rate of viruses found in activated sludge plant effluents (10 per cent). Since these are the only records of the removal of viruses by activated sludge at the plant, information on the mechanism must come from other sources. Carlson *et al.* (3) described the removal of mouse-adapted poliovirus from sewage by activated sludge in the laboratory as dependent on aeration and sludge presence, but gave no other clues to the mechanism. Reports of the removal of pathogenic bacteria by activated sludge mention their persistence in the sludge (4), the importance of the settling period (5), and the possible role of bacterial antagonism (6). In this study flocculation of the sludge did not entirely explain virus removal at the plant, since there was no concentration of viruses in the return sludge (Table I).

Several approaches were used to study the way in which viruses are removed by activated sludge. In doing so, it became clear that aerobic, mechanistic, metabolic, and antagonistic characteristics of the sludge were involved. This report attempts to describe these components and evaluate their role in the removal of viruses from sewage.

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Materials and Methods

Sludge was made in the laboratory, using as starter small volumes of aeration tank sludge from the Harlem Valley State Hospital at Wingdale, New York, and was maintained at room temperature in liter volumes. The starter sludge was stored at 5°C for periods of up to six weeks before use. Beyond that period it was no longer satisfactory. In the laboratory production of activated sludge the starter was diluted with from three to five times its volume of raw sewage and the mixture was aerated through a diffuser stone at the rate of from 21 to 22 l/hr. It was fed twice daily by the draw-and-fill method as follows: the liter of mixed liquor was allowed to settle one-half hour, and 500 ml of the supernatant fluid were replaced with an equal volume of raw sewage from the Albany treatment plant. About 100 ml of settled sludge were "wasted" daily. After two days of this schedule the activated sludge had volume indexes from 127 to 241 with mixed liquor solids from 678 to 1,180 mg/l, and often removed during a 4-hr aeration period 99 per cent or more of added virus. It was usually tested from two to five days after being started and over a 30-day period, the range of removal was from 94 to 99.9 per cent of added virus. Fresh sludge secured from the plant removed viruses in the laboratory to the same degree. After a 4-hr aeration period there was no significant change from the initial pH value of approximately 7.2. A preparation maintained with synthetic

TABLE I.—Isolation Rate and Plaque-Forming Units of Enteroviruses After Sewage Treatment

Treatment	Samples with Virus			Aggregate PFU/0.5 ml
	Effluent/Raw	Sludge/Raw	Per Cent Isolation	
Primary treatment				
Settling	64/69	—	93	—
Secondary treatment				
Trickling filters	34/49	—	70	—
Activated sludge	2/10	—	20	—
Return sludge	—	9/10	90	—
Chlorination in combination with other treatment	19/49	—	39	—
Activated sludge				
Raw	—	—	—	18
Aeration tank effluent	2/8	—	25	1
Return sludge	9/10	—	90	12
Effluent	2/10	—	20	0

sewage (7) removed no greater than 93 per cent of added virus.

In individual experiments to test virus-removing activity, one part of settled sludge from the former preparation was mixed with two parts of raw sewage to give mixed liquor volumes of 15 ml, a ratio found to be optimum. The mixtures were aerated in 175- × 22-mm tubes through capillary pipettes at a rate of from 12 to 14 l/hr. The stock preparation was fed with sewage one hour before the settled sludge was removed. In a few experiments with bacteriophage the raw sewage was sterilized by autoclaving to reduce the total number of host cells of *Escherichia coli* available for reproduction of the phage.

Viruses were added to the mixed liquors in the form of supernatant fluids from HeLa cells (8) infected with either poliovirus type 1, strain MK 500, or Coxsackie virus Group B, type 5, strain EA 80, in amounts to give from 1,000 to 10,000 50-per cent tissue culture infectious doses (TD_{50}) per 0.1 ml or from 1,000 to 100,000 plaque-forming units (PFU) per 0.5 ml. Several observations were also made with bacteriophage *E. coli* B, T_2 (9) in concentrations of from 300 to 5,000 plaques per ml. Estimates of initial and final concentrations of virus were made in 2-ml aliquots of the supernatant fluids after the mixed liquors had settled for from 15 min to ½ hr. TD_{50} were estimated in tube cultures of HeLa cells by the moving averages method (10) and PFU were counted in bottle cultures of monkey kidney tissue (11). The supernatant fluids were centrifuged at 3,000 rpm and filtered through membrane filters before inoculation into tissue cultures. Estimates of phage particles in the supernatant fluids were made (12) and in a few experiments in the settled sludge fraction after it had been centrifuged, washed, resuspended, and incubated one hour at 32°C with toluol (13) to reduce microbial contamination.

A few oxidation-reduction potential measurements were made of the mixed liquors with the pH meter using a platinum electrode with a saturated calomel half cell as a reference (14). The millivolt (mv) readings were standardized against that of a potassium acid phthalate buffer, 0.05 M, at pH 4.01, to which a trace of quinhydrone was added (15) and are expressed in relation to hydrogen electrode potentials.

Isolations of typical fungi and bacteria were made by picking colonies from agar plates streaked with loopfuls of settled sludge from the plant. The following media were used in accordance with (16): beef extract tryptone glucose agar, beef extract agar, beef heart infusion agar and horse blood, and Sabouraud's modified peptone agar, with glucose. A few isolations were made also on a modification of Tyrod's agar (17). Autoclaved sewage suspensions of slant cultures of the strains were made and screened for antiviral activity by aeration with poliovirus followed by settling in the manner described for observing the effects of activated sludge.

Results

The aerobic nature of the virus-removing activity of sludge was demonstrated directly by the exclusion of air and indirectly by noting the effects of substrates for and inhibitors of aerobic respiration. When nitrogen was bubbled through the mixed liquors at the rate of from 12 to 14 l/hr for periods of up to 5 hr, viruses were not removed. A rise in virus concentration was often noted in the supernatant fraction of mixed liquors which had been nitrogenated, for which no explanation is offered at present. Wuhrmann and Beust reported that glucose was removed by activated sludge under anaerobic conditions (18). In studies here, however, glucose in concentrations of 0.001 and 0.01 M had no effect on virus removal by activated sludge when nitrogenated, indicating that they are not parallel activities.

TABLE II.—Removal of Bacteriophage by Flocculation at Various Metabolic States of Activated Sludge; Sludge Fed at Zero Hour

Item	Aeration Period of Mixed Liquors (hr)	Per Cent Removal After Settling	
		Experiment 1	Experiment 2
Aeration prior to addition of phage and settling	1	0	10
	2	17	34
	4	24	44
	6	30	—
Phage added prior to aeration and settling	1	7	—
	2	55	—
	4	43	98
	6	51	—

Malonic acid, the specific inhibitor of the respiratory enzyme, succinic acid dehydrogenase, in nonvirucidal concentrations of 0.001 and 0.01 M, reduced the virus-removing activity of sludge by about one-fifth. The respiratory stimulant, dinitrophenol (DNP) did not enhance the virus-removing activity of sludge in concentrations of from 0.00001 to 0.1 M. These results do not concur with those reported (19) in which concentrations of DNP of from 0.0003 M up to 0.0002 M increased the organic fraction reducing activity of sludge when aerated for two and a half hours or less in a medium of synthetic sewage.

While the preceding experiments demonstrate the necessity of aeration for the virus-removing activity of activated sludge, aeration itself is not the mechanism. Aeration of sewage-virus mixtures, in the absence of sludge, for periods of up to five hours, did not reduce the concentration of polioviruses, or bacteriophage. When mixed liquor was aerated in the presence of bacteriophage, the removal of phage during the settling period was greater than when it was added to the mixed liquor after the aeration and prior to settling (Table II). When the mixed liquors were aerated for different periods of time, the longer aeration periods resulted in greater removal of phage whether or not the phage was present during or added after aeration. In no case, however, was the per cent removal of phage as great, when it was added after, as when present during aeration. These experiments demonstrate that about half the virus removed by activated sludge may be accomplished while the sludge

TABLE III.—Removal of Poliovirus and Bacteriophage from Sewage by Dispersed and Intact Floc of Activated Sludge; PFU in Thousands (Data are from a typical experiment)

Hours of Aeration	Intact				Dispersed			
	Poliovirus		Phage		Poliovirus		Phage	
	PFU/0.5 ml	% Removal	PFU/ml	% Removal	PFU/0.5 ml	% Removal	PFU/ml	% Removal
0	550	—	4,900	—	767	—	5,700	—
2	185	66	2,500	49	277	64	3,100	45
4	120	78	3,300	33	273	64	3,500	39

is settling although a substantial proportion is accomplished during aeration in the presence of sludge.

The importance of the oxidation-reduction potential (ORP) of activated sludge in removing viruses was considered by comparing it with the redox potential of a solution in which enteroviruses are commonly stored, 199H. The ORP of aerating mixed liquor immediately after feeding with raw sewage varied from +185 mv initially to +285 mv 20 min later. The potential 6 hr after feeding ranged from +340 mv initially to +315 mv after the electrodes had been immersed 30 min. The ORP of 199H was +360 mv initially, indicating that the removal of virus by activated sludge was probably not a function of the redox potential itself. The role of rapid changes in potential, as from those in raw sewage to those after brief aeration with sludge was not examined.

The mechanical properties of the sludge appeared to be of minor importance in the removal of virus from sewage when observed as follows: sludge which had been dispersed before aeration by agitation in a blender for 5 min at 10°C removed poliovirus to the same extent as intact sludge during a 4-hr aeration and a half-hour settling period (Table III).

The mechanism for the removal of virus during aeration in the presence of sludge floc may well be more complex than that during the settling period which may be partially explained by adsorption or exchange. Evidence of enzymic activity was sought for as follows: the supernatant fluid from activated sludge, fed with sewage two hours previously, was aerated five hours in the presence of virus. No change in phage concentration was noted, indicating the absence of exoenzyme activity. Nor did a cell-free aqueous extract of freshly fed sludge, made by grinding sedimented sludge with powdered Pyrex glass, remove phage from sewage after a three-and-a-half-hour aeration period, indicating the absence of endoenzyme activity.

The question persists as to what happens to the virus that is removed. If a buildup of viruses occurred in the sludge, the density of viruses in that portion would be enormously greater than that of raw sewage. Isolations of virus in return sludge at the plant did not confirm this. In the laboratory the failure of virus to accumulate in the settled sludge was verified in this manner: the total number of phage particles in the mixed liquor (supernatant

TABLE IV.—Recovery of Bacteriophage in Various Fractions of Activated Sludge

Fraction	Plaques/Sample*		Per Cent Removal
	Aeration Period (hr)		
	0	5	
Supernate	28,700	285	99.1
Sludge	4,515	3,130	30.7
Total	33,215	3,415	89.7

* Data from a typical experiment in duplicate.

fluid plus settled sludge) was estimated by summing the numbers found in the supernatant and settled portions before and after aeration. From 5 to 35 per cent of the added phage in the mixed liquor was recovered (Table IV). The decrease in phage concentration in sewage, however, was not reflected by an increase in its concentration in settled sludge, indicating that inactivation occurred during the removal process. The decrease was noted in both phases of the mixed liquor. Bacteriophage was chosen for this experiment since quantitative recovery from settled sludge of viruses which require sterile conditions for estimates of concentration is difficult. The possibility that phage was present in sludge in a bound state not detectable by the usual test was considered and found to be improbable: the charge on the sludge particles was changed by adjusting the pH to 4.0 and by reducing the number of diffusible ions by dialysis overnight against running tap water. In both instances the phage concentration of the sedimented sludge was no greater than before.

The failure to recover additional virus in the return sludge in plant operations and in sedimented sludge in the laboratory strongly suggested that inactivation occurs during the aeration process. Oxidation by contact with molecular oxygen was not a likely mechanism of inactivation since aeration in sewage alone did not inactivate virus. While it was possible that chemical antagonism from components of the sludge inactivated virus, an aqueous extract was ineffective.

The possibility that biological antagonism in sludge plays a role in the inactivation of viruses was explored by screening microbial isolates from sludge for their virucidal activity. Of 58 strains isolated, 4 inactivated from 50 to 90 per cent of initial virus in duplicate screenings. At least six others inactivated to that extent in single tests. The antiviral effect of four of the strains tested as a mixture was no greater than that of the strains tested separately. The remaining isolates were ineffective or inconsistent in duplicate tests. The virucidal isolates were characteristic of *Flavobacterium*, *Klebsiella aerobacter*, and coliform strains (20). Voleani has identified a virus-destroying soil organism as a *Flavobacterium* (21). None of the isolates of fungi were virucidal.

Discussion

The mechanism for the removal of enteroviruses from sewage by activated sludge is complex. The obvious mode, flocculation followed by settling, however, accounts for only a portion of the removal. The remainder of the removal was carried out during the aeration process in the presence of sludge floc and nutrients. The aeration process, further, was found to "prepare" the floc for clarifying activities during settling.

If McKinney's interpretation of activated sludge cycles (22) is applied to the removal of viruses, the aeration period with nutrient serves to put the organisms of the floc in a state of endogenous respiration after which time (in experiments here, at least two hours after feeding) the removal of viruses may be accomplished by the flocculation process.

Unexplained, however, is the removal that occurs during aeration in the presence of sludge floc and the fate of the virus removed by flocculation. The ecological character of activated sludge —aeration, nutrients, microorganisms, foreign matter—strongly suggests an area ripe for the elaboration of biological antagonists. Furthermore, the relative sluggishness of the system—two to four hours required for inactivation —is indicative of a biological rather than a chemical oxidation, in which a latent period of unobvious activity may be necessary. In this framework the antiviral activity of some of the bacterial isolates from activated sludge is

not surprising. The continued action of these biological antagonists during flocculation and settling may well account for the inactivation of virus that accompanies its removal. The importance of the mechanical state of the floc in removing viruses is lessened if antagonism is assigned a role, and this was observed.

The possibility was not explored that auto-inactivation of viruses occurs as a result of depletion of some essential nutrient or stabilizer by activated sludge. This is suggested by the need for tryptophane by *Salmonella* in anaerobically digested sludge (23) and by the account that phosphorus, a factor in virus survival in water, is rapidly removed by activated sludge (24).

The effects of respiratory substrates and inhibitors on virus removal by sludge are indicative of its aerobic nature. The results are less clear cut than expected, perhaps because of the many systems in sludge that are susceptible to these compounds.

Summary

The removal of poliovirus and bacteriophage by activated sludge in the laboratory was shown to involve at least two steps: (*a*) aeration in the presence of sludge floc and nutrient, and (*b*) the settling of floc. Removal by the latter step depended on the metabolic state of the floc. Aeration with sludge floc was essential and was affected by respiratory metabolites and the absence of air. Aeration itself had no effect, and the redox potential was not implicated. Nor was the mechanical stability of the floc vital in virus removal. Viruses were inactivated during the removal process, and the isolation of at least four strains of bacteria with antiviral activity suggests that biological antagonism is a third step.

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CONSTRUCTION CONTRACTS

Did you know that sewerage construction is heading for a record year? The cumulative volume in the first 8 months totaled $502 million, a 25-per cent increase over the same period last year.

LEGAL RESPONSIBILITY OF SEWAGE PLANT OPERATORS

John S. Samson

It has been said, "Every phase of the far reaching enterprise of pollution control is necessarily governed by law. Hence it is important not only for legal counsel, but for members of governing bodies, administrators, technicians, and others who are engaged in pollution control work or are affected thereby to have at least a working knowledge of the principal provisions of laws to which they are subject" (1).

In view of the fact that there are many more phases of the law involved as it relates to the topic than can be covered in a short paper, this is restricted to a few general principles of legal responsibility of an operator.

Most operators but few lay citizens are aware that, "The most complete and efficient types of sewage treatment utilized today, do not of themselves produce water of a quality that is potable." The self-purification processes of the water into which the treated sewage effluents are discharged are essential to raise the quality of the water. To go on from this, further purification is necessary when the river water is withdrawn for domestic purposes. Depending on the degree of pollution of the water source, water disinfection, coagulation, sedimentation, and filtration are necessary." In this connection many branches of government, including the United States Public Health Service and industry, including but surely not restricted to oil, steel, paper, packing, and mining through engineering and scientific approaches are seeking to find methods which hopefully will guarantee close to 100 per cent removal of the various impurities from used water.

This is mentioned to emphasize that no legal liability should attach to the operator—the agent or to his employer—the principal—in most cases the municipality, because the effluent is not as such, potable. Sanitary engineering has not yet progressed to and developed methods where such effluent may be in and of itself potable.

There are different means of protection which can be employed to protect the sewage plant operator as to liability. Some of these are:

1. State legislation holding the city responsible.
2. Personal liability insurance.
3. Some method of indemnification by the city to the operator.

Mandatory Operator Certification

The items just mentioned result in protecting the operator, only, against damages. What of the private citizen who is injured as a result of the operator's negligence or incompetence?

One possible answer is a program of training with rigid requirements for the sewage treatment plant personnel. Many of the states' water pollution control agencies are meeting this need through their certification programs (2). Seven states have mandatory or compulsory certification programs and

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thirty-five have voluntary programs. Michigan and New York, together with Illinois, New Jersey, Ohio, West Virginia, and Texas using mandatory certification with Florida being one of the states utilizing voluntary certification program. It is most interesting to note that Nebraska has no plan for certification (3) even though "interest" was high in this matter back in 1951 (4).

The certification of water and sewage treatment plant operators is done with but one objective in mind—to make reasonably certain that treatment facilities will be operated efficiently and effectively. The objective can be fulfilled only by employment of qualified, competent operating personnel on a continuing basis. The method for accomplishment may vary from state to state, but the basic objective remains the same (5). Insight as to why some states are delinquent and also why mandatory certification is considered superior to voluntary is necessary in considering this problem. The initial support for a certification plan should have a broad base. This means that all groups which may have an interest in certification must be contacted and kept informed. Their support must be solicited. A municipality or industry may very easily come to suspect that a plan backed only by plant operators is solely for the operator's protection (6). Either type of certification is an improvement over the utilization of incompetent personnel, for not only will the public benefit, but the sewage treatment plant fraternity of operators will experience a better life through increased earnings and education (7).

With certification, water pollution control work would become more professionalized, the appointments with tenure of office less susceptible to the whims and whimsy of the local politician, with a salary commensurate with the capabilities and abilities of the involved person leading to greater stability in the employment relationship.

Negligence

The rule to avoid the charge of negligence is: "Be careful and do what a reasonably prudent man under the circumstances would do." Do not place yourself in the category where you would qualify as being negligent. The courts have defined negligence as, "The omission to do something which a reasonable man guided by those ordinary considerations which ordinarily regulate human affairs, would do, or the doing of something which a reasonable and prudent man would not do" (8).

Distinction Between Governmental Functions and Proprietary Functions

The maxim, "The king can do no wrong," underlying the common law immunity from suit of the sovereign, is the foundation upon which the immunity from suit of the state, and, in turn, of the city, is based. At common law, the early Russell Case (Russell vs. Devon County, 2 TR 667-12 English Ruling Cases 694–1788) is generally regarded, although this is disputed by some as having established in 1788, the fundamental principle that a political subdivision of the state was not liable for injury resulting from its negligence in performance of a governmental function.

In our early American history, municipal corporations were placed on the same footing as private corporations insofar as tort liability was concerned and sovereign immunity was not extended to them. This was changed in 1842 when the landmark Bailey Case (Bailey vs. New York, 3 Hill NY 531, 38 AM Dec. 669–1842) was decided and since then the fundamental legal principle underlying municipal tort liability has remained practically unchanged (9).

In this case the city was held liable in an action for damages to property due to negligence in the construction of a water-

supply dam upon the theory the city was in the same legal position as a private corporation. But the court plainly indicated that the city would have been immune from liability if it had been acting in its public character, that is, engaged in a governmental function. Thus was evolved the municipal tort liability doctrine now generally recognized, that a city has both proprietary and governmental functions and that it may be liable for torts arising out of its proprietary activities but is immune from liability for torts arising out of its governmental functions.

As has been said (10),

> The law has always made a distinction in the liability of a government when it is acting as a government and its liability when it is acting in a proprietary capacity or, more simply, when it is engaged in a business enterprise. It has always been the case that when acting in a business enterprise, a government is liable, just as any other business enterprise. Examples of such activity are the water department, gas department, harbor department, municipal auditorium and stadium, municipal airport, electric utility and other similar activities of many municipalities. In general, all are business or proprietary activities.

And further (9),

> The rule recognized by the great weight of authority is that in the absence of statutory provisions to the contrary a city is not liable for injuries caused by its negligence or nonfeasance in the exercise of its governmental functions, this being a common law rule which immunizes the city against liability for either the nonuse or misuse of its governmental power or for the acts or omissions to act of its officers, employees and agents. But it is liable for its torts committed in its proprietary capacity. Although differences in judicial opinions may make a municipal function governmental in one jurisdiction and proprietary in another, in general the distinction generally recognized is that if the function is for the benefit of the public at large it is governmental and if solely for the people of the community or the city itself, it is proprietary. Perhaps the most commonly accepted distinction between governmental and proprietary functions is based upon what or who is affected by the exercise of the function, that is, if the state or the public generally is the principal beneficiary is the municipal corporation and its inhabitants it is proprietary.

It seems to be the generally recognized rule that a municipality is liable, to the same extent as a private corporation, for injuries resulting from the creation or maintenance of a nuisance by a municipality (9), and thus the maintenance and operation of a municipal sewage disposal plant could impose municipal liability (11).

Status of the Wastewater Treatment Plant Operation

The following are noted as relative to wastewater disposal plants (14):

> Wastewater disposal plants. Although authorities are in conflict upon the question as to whether the operation of a sewage disposal plant is a governmental or a proprietary function, the prevailing view seems to be that a municipality may be held liable for death or injury resulting from negligent or other tort in the operation of such a plant. Likewise, irrespective of negligence, and even though it is constructed and maintained under statutory authority or in the performance of a governmental function, a municipal corporation may be held liable if a nuisance results from operation and maintenance of a septic tank, or other sewage disposal system. In a proper case, such a nuisance may be enjoined, but, under appropriate pleadings and proof, an injunction may be denied under the doctrine of comparative injury, or on condition that the noxious situation be corrected.
>
> An owner of land taken for the construction of a sewage disposal plant is entitled to an award of the value of the land taken and consequential damages to his business.

and noted further in (12):

> The general rule with respect to the rights of property owners, such as plain-

tiffs, who are damaged as a result of the flow of sewage across their property, as follows: 'A municipality is answerable in damages if it discharges the outflow of a sewer, or a system of sewerage upon the property of another, and this upon the ground that such discharge constitutes a private nuisance for which action may be maintained by the person injured.

A municipality has no more right to create a nuisance to the injury of another than has an individual, and hence where a sewer outlet is a private nuisance damages are recoverable. Thus, a municipality will be liable where a sewer is maintained by a municipal corporation so as to discharge sewage and filth upon private property, or to emit offensive odors creating an insanitary and dangerous condition interfering with the safe and comfortable enjoyment of such property so as to impair its value. The Kansas Court on King vs. Kansas City, 58 Kan. 334, 338, 49 P. 88, 89, declared that a municipality cannot collect 'sewage and filth and precipitate it upon the property of a citizen . . . even if the plan is devised in good faith and the best material is used in the construction. It is immaterial from which end of the sewer the discharge is made. The consequence and liability are necessarily the same.

This Court in Winchell vs. City of Waukesha, 1901, 110 Wis. 101, 109, 85 N. W. 558, 670, declared:

> The great weight of authority, American and English, supports the view that legislative authority to install a sewer system carries no implication of authority to create or maintain a nuisance, and that it matters not whether such nuisance results from negligence or from the plan adopted. If such nuisance be created, the same remedies may be invoked as if the perpetrator were an individual.

Three Supreme Court decisions refer to the same problem, one from Wisconsin, one from North Dakota, and the other one from Washington.

In Briggson vs. City of Viroqua, 264 Wisc. 47, 58 NW 2nd 546:

> The plaintiffs are the owners of a 110 acre farm located approximately one mile to the northwest of the sewage disposal plant of the City of Viroqua. The City of Viroqua is the county seat of Vernon County and has a population of approximately 3,500. In the early 1920's it constructed two sewage disposal plants, one at the southeast corner of the city, and another at the northwest corner of the city. Some years later the smaller plant at the southeast corner of the city was abandoned and all sewage was sent through the plant at the northwest corner of the city, a pumping station being employed to lift the sewage from the south side of the city so that it could be transported to the plant at the northwest corner of the city.
>
> The sewage disposal plant is equipped with a bi-pass valve and when such valve is opened raw sewage is precipitated down the valley and across plaintiffs' property. The plant was not so constructed with sufficient capacity to handle the storm water of the City of Viroqua which enters the city's sewer system. In case of heavy rains the bi-pass valve was then opened so as not to overload the capacity of the plant itself, with the result that raw sewage was permitted to flow directly down the valley. It was only natural that a terrible stench arose as a result thereof and continued for a long time after the bi-pass valve had again been closed, because of the precipitation of the solid matter along the sides of the ditch created by the effluent. At times the odors were so bad in the summertime that the tenants were obliged to keep the doors and windows closed of the dwelling house located upon plaintiffs' land. Cows of the tenants pastured in the area had to be cleaned with disinfectant before they could be milked. The well on plaintiffs' farm was contaminated and its use for drinking purposes permanently destroyed so that the tenants were obliged to haul all of their drinking water from outside sources.

The Supreme Court affirmed a $5,000 damage judgment and reversed the lower court in that it held the plaintiff was entitled to a permanent injunction.

In the case of Kinnischtzke vs. City of Glen Ullin (North Dakota) 57 NW 2nd 588:

The complaint alleges that the plaintiff owns 640 acres of land approximately one-half mile from the City of Glen Ullin and maintains thereon his home and residence for his family. It is then alleged that the defendant carelessly and negligently operates its sewer system and cesspool and by reason of such negligence causes the city sewage and offal to be discharged into a creek, which flows through and adjacent to the Plaintiff's premises and home, causing a nauseating stench that has greatly damaged the plaintiff personally and injured the value of the premises; that plaintiff's livestock drink the water from said creek an that as a result of the pollution the plaintiff's cattle have become greatly emaciated and reduced in value.

There was a judgment for the plaintiff and on appeal the Supreme Court held that where a municipality purposely or negligently so operates a sewage disposal plant that it becomes a nuisance which results in injury to property, the municipality is liable for damages.

Public Employee Liability

The case of Russell vs. City of Grandview (Washington), 236 P 2nd 1061, answers two questions. The two defendants were the City of Grandview and Earl Bugge, water superintendent.

On and prior to October 26, 1949, the City of Grandview owned and operated a municipal water plant for the purpose of furnishing a domestic water supply to its inhabitants. The water was pumped from wells into the distribution system. Combustible gas from the wells affected the water pressure. The water superintendent informed respondents that if they would leave the faucets open the gas pressure would be released and the water would soon flow.

On the morning of October 26th, the respondents had no flow of water. Two sink faucets and those serving the bath tub and wash basin were opened. Shortly thereafter, hissing sounds were heard coming from the faucets. While one of respondents was preparing breakfast on the kitchen stove, the gas that had come into the home exploded, injuring respondents, wrecking the dwelling house, and causing fire damage.

In affirming a damage judgment for the plaintiff, the Supreme Court said:

In the performance of its duties owing to its patrons, the city acted by and through the water superintendent. It was his duty to exercise reasonable and ordinary care to so operate the water system under his charge as to prevent the entering of explosive gas into the water pipes. It was his acts and omissions which to a great extent, though not exclusively so, incurred liability on the part of the city. It is elementary that an agent whose negligent acts or omissions in the performance of the duties entrusted to him renders his principal liable in damages, is also liable for his own negligence. The court properly submitted the question of negligence on the part of the water superintendent to the jury.

City engaged in operation of water system acts in its proprietary capacity and is liable for negligence the same as any private corporation engaged in such business, and fact that some of the water is used in connection with health and sanitation and in fire protection is immaterial.

The above shows how the negligence of a public employee involved him personally.

It may be said any employee who negligently, or intentionally for that matter, injures another person or his property, may be personally responsible for the damage he causes; this whether or not he works for the city in its proprietary capacity or governmental capacity. As a municipal employee he is an agent of the city and of course the city, if acting in a proprietary capacity, is also liable (10).

An agent is liable to a third person for his own misfeasance or positive wrongs although in some cases there appears to be a thin line which separates the above from nonfeasances or omission of duty in course of employment. Generally an agent who violates

a duty which he owes to a third person is answerable for the consequences thereof; is liable for his own act regardless of whether the principal is liable or amenable to judicial action (16).

As a well-known legal works sets out (17):

> It is clear that the relation of agency does not exempt a person from liability for an injury to a third person resulting from his negligence for which he would otherwise be liable. An agent is liable to a third person for any injuries incurred by the latter as the proximate result of the agent's failure to use due care. This liability is based not upon the relationship of principal and agent, but upon the common-law duty resting upon every person—agent or not agent—to use due care and proper precautions so that he does not act or use that which he controls so as proximately and negligently to injure another person. In other works, this liability, even though it may arise out of the performance of the agency work or transaction, rests upon a breach of duty to such third persons which exists, not because of the agency, but regardless of it.

In a text of the American Law Institute which is increasingly referred to by both the judiciary and the members of the bar expresses the broad principle that an agent is subject to liability, if by his acts he creates an unreasonable risk of harm to the interests of others protected against negligent invasion; verbatim it is (18):

> An agent is subject to liability if, by his acts, he creates an unreasonable risk of harm to the interests of others protected against negligent invasion.

also (19),

> These sections include situations in which an agent causes harm to a third person by his activities, and also those in which the agent's performance of his duties to his principal results in harm to third persons. It would be supererogatory to cite the innumerable cases dealing with the liability of an agent for his activities. An agent is not protected by the fact that he is acting as an agent unless he is privileged to act because of some privilege of the principal or unless the principal does not owe to a particular person the standard duty of care. Where, however, the agent's conduct is a failure to do something, rather than doing something wrong, there is more difficulty in reconciling the cases and there are undoubtedly courts which make the distinction once made between nonfeasance and misfeasance.

As has been so well said (20):

> Municipalities whose sewage disposal systems have resulted in a nuisance to private parties have often sought to defend suits brought by such individuals upon the ground that the construction and operation of a sewage disposal plant involve a pubic necessity, and, when sanctioned by legislative authority, constitute a governmental function immune to the suits of private parties. The question is sometimes further complicated by the existence of constitutional provisions requiring the payment of compensation for the "taking," and in some cases for the "damaging," of private property. The courts have been nearly unanimous in rejecting the contention that a municipality is immune from suit, either for damages or for abatement of the nuisance, merely because the offending sewage disposal plant has been constructed and operated under legislative authority. The reason most frequently given for rejecting the governmental immunity contention is that while the legislature may have sanctioned the construction and operation of the sewage disposal plant, and while the exigencies of the public may require it, yet it is not to be inferred that the legislature intended to sanction the creation and maintenance of a nuisance. The view that a municipality may not escape liability for the construction or maintenance of a sewage disposal plant constituting a nuisance, whether on the theory of public necessity or statutory authorization, is upheld in 18 jurisdictions including Nebraska in Hall vs. Friend (1938) 134 Nebr. 652, 279 NW 2nd 346.

In Nebraska, the Supreme Court beginning back 1878—Davis vs. Lond-

green, Vol. 8 Nebraska Reports 43; Barton vs. Union Cattle Company, 44 NW 454 (1889); Abraham vs. City of Fremont, 74 NW 834 (1898); Todel vs. City of York, 92 NW 1040 (1902); and Hall vs. Friend, 279 NW 346 (1938) have had under consideration and for determination various phases of sewage disposal problems.

A Sewage Treatment Plant per se or per accidens is not a Nuisance

Lest an impression may be left that sewage disposal plants are per se or per accidens a nuisance, the courts seem to uniformly hold they are not. Beginning with the construction of the modern systems of septic treatment at a plant built in 1894 in Urbana, Illinois, with a first installation of an Imhoff plant in Philadelphia in 1911 and the continual advance in the use of scientific methods for the treatment and disposal of sewage, although of comparatively recent origin, a position that such a plant is a nuisance per se is unwarranted (18).

Most courts have taken the view that injunctive relief against proposed construction and operation of a sewage disposal plant does not appear warranted on the grounds of anticipatory nuisance (19).

The manner of operating a sewage disposal plant may constitute a nuisance and in that connection the overwhelming weight of authority is:

> Dealing, therefore, with the broad question whether a sewage disposal plant is a nuisance per se, and taking into consideration the factors already discussed earlier in this section, it would appear as a general rule that while a sewage disposal plant is not per se a nuisance, it may be so constructed or maintained that, through the emission of noxious or disagreeable odors, or through the discharge of improperly digested sewage upon land or into a watercourse, it becomes a nuisance in fact or per accidens (20).

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DEGRADATION OF CELLULOSE BY ACTIVATED SLUDGE TREATMENT

E. Hurwitz, A. J. Beck, E. Sakellariou, and M. Krup

The disposal of sewage solids is a major problem in most communities. In metropolitan communities, like Chicago and Milwaukee, where ultimate disposal requires the production of a marketable end-product, any condition which affects this marketability aggravates the disposal problem.

Chicago was faced with such a problem. Early in 1958, a decided change in the physical characteristics of the heat dried activated sludge produced at the Southwest Treatment Works was noted. The material took on a bulky quality. Instead of a normal granular form, the particulate matter became very fibrous. These fibers "balled-up" in the mechanical handling devices and caused outages of the equipment. They also interfered with packaging by jamming the packaging machinery and because of the low weight to volume ratio, it was often difficult to use standard size bags.

Examination of this fibrous material indicated that it was largely cellulose. However, the trouble disappeared after 6 or 8 weeks and nothing was done at the time to determine the cause or to develop a remedy.

There were several possible reasons for the appearance of this "fluff" and several theories were advanced for its resistance to treatment. The most plausible theory was one which took into consideration temperature change and its effect on biological action.

In order to develop this theory, a reliable method for the determination of cellulose in sewage solids was developed. This was a modification of the method of Waksman and Heukelekian (1) which is described later.

Cellulose is a regular constituent of domestic sewage but few references are found in literature relating to its content in sewage. Heukelekian and Balmat (2) reported 5.6-per cent cellulose in the particulate matter of sewage under winter conditions and 4.1 per cent under summer conditions. Metcalf and Eddy (3) estimated that out of a total of 183 g/cap for residential sewage, 20 g are cellulose in the form of newspaper and toilet paper. Generally cellulose, as such, receives little attention in sewage treatment. This is so because much of it is easily settled out in preliminary settling tanks and because it does not impose a significant load on biological treatment processes. It may even be looked upon as beneficial in that it forms a matrix on which the zoogloea, responsible for biological treatment, build.

Seasonal Influence on Cellulosic Content of Activated Sludge

The excessive fibrous condition of the dried activated sludge which was first noted in January of 1958, reappeared at about the same time in 1959 with even greater intensity. In October of that year regular analyses for cellulose of the feed to the vacuum filters (return sludge) was started using the method developed for this purpose. These analyses were continued through a complete cycle of a year to observe the seasonal influence on cellulose content (Table I).

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The cellulose content increased gradually from 1.0 per cent in October 1959 to 3.55 per cent in February 1960. At this time the dried sludge again became light and fluffy with accompanying cellulosic material. The conditions improved slowly in March and April. In May, the cellulose in the dried sludge was reduced to 1.57 per cent and it was again suitable for marketing. During July, August, September, and October the cellulose content continued to decline, to the lowest value of 0.61 per cent.

With the onset of colder weather, there was a gradual rise to a maximum of 2.46 per cent in February 1961, followed by gradual decline to 1.82 per cent in March 1961. The change in cellulosic content was accompanied by changes in weight-volume ratio of the dried sludge which was inversely proportional to the amount of cellulose.

TABLE I.—Per cent Cellulose in Filter Feed (Return Sludge)

Year	Month	Cellulose (%)	Fertilizer (lb./cu ft)	Sewage Temp. (°F)
1959	Oct.	1.04	—	—
	Nov.	1.30	—	60
	Dec.	1.93	—	56
1960	Jan.	2.19	—	53
	Feb.	3.55	30.9	52
	March	3.17	30.3	52
	April	2.64	34.6	57
	May	1.57	37.6	63
	June	1.11	39.0	69
	July	0.71	40.8	74
	Aug.	0.70	41.3	77
	Sept.	0.73	39.8	76
	Oct.	0.61	40.0	72
	Nov.	0.91	38.6	64
	Dec.	1.36	38.1	54
1961	Jan.	2.22	34.0	53
	Feb.	2.46	33.4	54
	March	1.82	37.2	52

Seasonal Variations in Cellulose Content in Raw and Settled Sewage

At the same time the seasonal variations in cellulosic content in raw and settled sewage at the four Sanitary District sewage treatment plants was investigated (Table II).

The cellulose content of the raw sewage at the Southwest Plant is reasonably constant in the range of 4.5 to 6 per cent. The same constancy is true of the West Side Plant, but at a higher value, 6 to 8 per cent. The reverse is true for the settled sewage. The long settling period (2½ hr) in the West Side Imhoff tanks removed appreciably more cellulose than was removed during the short settling (30 min) provided by the primary tanks at the Southwest Plant. There does not seem to be any significant seasonal variation

TABLE II.—Cellulose in Wastewater Treatment Plants

Year	Month	Southwest			West		North			Calumet		
		Raw (%)	Settled (%)	Filter Feed* (%)	Raw (%)	Settled (%)	Raw (%)	Settled (%)	Return Sludge (%)	Raw (%)	Settled (%)	Return Sludge (%)
1960	June	6.54	3.37	1.11	7.05	2.96	—	—	—	—	—	—
	July	3.77	2.33	0.71	5.89	1.25	5.14	4.48	3.48	3.22	1.66	1.06
	Aug.	2.71	1.91	0.70	7.70	2.04	5.44	3.65	2.57	4.79	2.75	1.91
	Sept.	4.30	3.45	0.73	6.52	1.90	8.61	6.51	3.11	6.39	4.03	1.62
	Oct.	4.34	2.57	0.61	5.54	1.01	11.21	10.11	3.30	8.35	4.83	1.80
	Nov.	4.79	4.34	0.91	5.34	1.39	11.68	7.11	3.78	7.23	5.46	1.36
	Dec.	5.26	4.06	1.36	8.51	2.44	10.97	9.72	5.26	8.60	8.30	2.68
1961	Jan.	5.73	5.11	2.22	6.98	2.00	13.52	9.69	6.99	9.92	7.66	4.84
	Feb.	6.11	4.74	2.46	8.11	2.94	12.74	10.16	8.87	10.55	8.19	7.54
	Mar.	4.69	4.37	1.82	7.11	1.89	8.80	6.72	7.60	7.07	6.06	4.90

* Filter feed and sludge return are identical at the Southside Plant.

TABLE III.—Effect of Temperature on Sludge Degradation

Aeration Period (hr)	Temperature Range (°F)	Aeration Solids (mg/l)	Cellulose in Sample (%)	Cellulose Degraded (%)
0	53–55	5,295	9.91	—
72	53–55	5,234	9.25	6.7
96	53–55	4,930	7.94	19.9
0	73–74	5,629	8.58	—
72	73–74	5,233	1.12	86.9
96	73–74	5,233	1.05	87.7

in the raw or settled sewage at these plants. However, at the North Side and at the Calumet plants there are marked seasonal variations in the cellulose content of the raw and settled sewages. The winter sewages contain twice as much as the summer. These seasonal variations are also reflected in the sludge return solids at the Southwest, North Side, and Calumet plants.

Degradation of Cellulose in the Activated Sludge Process

There is an abundance of literature concerning the decomposition of cellulose in nature. The bibliographies in the work of Siu (4) are replete with reference to cellulose degradation in the soil and in textiles but only passing reference is made to degradation in sewage. This reference is to the work of Buswell and Boruff (5) and Heukelekian (6) and concerns degradation under anaerobic conditions. Little appears to be known about the behavior of cellulose under aerobic sewage treatment processes.

Observations of the seasonal changes in the cellulose content of the sludges at the three activated sludge plants of the Metropolitan Sanitary District of Greater Chicago indicate definitely that cellulose is degraded under aerobic conditions. These results are shown for the Southwest, North Side, and Calumet plants in Table II. At each plant there is an appreciable reduction in cellulose content by aerobic treatment. The cellulose reduction falls off markedly during the cold months and gradually recovers as the warm season approaches. This indicates that temperature is the environmental factor limiting the activity of the cellulose degrading organisms.

The effect of temperature was further established by laboratory experiments in which mixed liquor sludge solids were aerated in parallel units at temperature ranges from 53 to 55°F and 73 to 74°F (Table III).

In the 53 to 55°F range only 6.7 per cent of the cellulose originally in the sample was degraded after 72 hr compared with 86.9 per cent in the 73 to 74°F range. After 96 hr aeration the reduction in the 53 to 55°F series increased to 19.9 per cent. In the 73 to 74°F range the reduction increased only slightly in the interval between 72 and 96 hr. It is apparent that the inhibiting effect of low temperature

TABLE IV.—The Effect of Sludge Concentration on Cellulose Degradation

Year	Month	Mixed Liquor Solids (mg/l)			Sludge Age (days)			Cellulose in Return Sludge (%)			DO Mixed Liquor (mg/l)		
		Tank Series			Tank Series			Tank Series			Tank Series		
		B	A	C	B	A	C	B	A	C	B	A	C
1960	Nov.	2,267	2,914	4,093	4.4	5.8	8.2	1.29	1.10	0.88	5.9	4.6	5.3
↓	Dec.	2,310	2,520	3,940	4.6	5.4	7.9	1.89	1.64	1.03	7.0	6.3	6.5
1961	Jan.	2,627	3,001	4,125	5.2	6.0	8.2	3.45	2.40	1.53	7.1	6.3	6.3
	Feb.	2,517	2,850	3,899	5.0	5.7	7.8	3.34	3.06	2.07	7.2	5.1	6.2
↓	Mar.	3,300	3,670	3,980	6.6	7.3	7.9	2.09	2.59	1.49	6.9	5.5	6.3

was rapidly overcome by the mass of organisms (5,000 mg/l aeration solids). The rate of cellulose degradation increased from 2 per cent per day during the first 72 hr to 13 per cent per day during the next 24 hr. This rapid increase in rate of cellulose degradation would probably continue until the available cellulose was exhausted. The high temperature series reached the point of no return within the first 72 hr at a rate of 29 per cent per day and then practically ceased. The easily assimilated available cellulose apparently was used.

Mixed Liquor Solids Concentration as a Factor in Cellulose Reduction

The effect of mixed liquor solids concentration on cellulose degradation was further borne out by plant-scale experience. For a period of several months during the 1960–61 winter season, each of the series of aeration tanks at the Southwest Plant was held at a different aeration mixture concentration. Tank series A was held at 2,500 to 3,000 mg/l; Tank series B at 2,000 to 2,500; and Tank series C at 3,500 to 4,000. Cellulose content of the return sludge was determined at regular intervals (Table IV).

Tank series C with the highest solids in the aeration mixture consistently showed the lowest cellulose content; Series B with the lowest aeration solids had the highest cellulose content; and Series A with the intermediate aeration solids showed a cellulose content between that of C and B.

These results indicate that cellulose degradation by activated sludge is increased proportionally to the mixed liquor suspended solids concentration. Since the MLSS concentration determines the sludge age, degradation is a function of the sludge age. The longer the solids are retained in the system, the greater will be the degree of cellulose degradation. The tests also indicate that the effect of low temperature on the activity of cellulose degrading organisms can be overcome by increasing the mass of organisms.

Determining Cellulose in Sewage Sludges

The method used for the determination of cellulose was a modification of one developed by Waksman and Heukelekian (1) for cellulose in soils.

Cellulose, acting as a weak acid, forms soluble copper complexes with cupric hydroxide in alkaline solution. On acidifying, the mixture and diluting cellulose, is precipitated. This principle is made use of in the separation of cellulose from protein and other impurities.

Schweitzer reagent, cuprammonium hydroxide solution, is an excellent solvent for cellulose. Tests with the commercially prepared reagent gave unreliable results. After experimenting with a number of methods for the preparation of the reagent, one was developed which was rapid, effective, and produced consistent results. This is described under the paragraph on preparation of reagents.

Other problems that required solution before final acceptance of a method for cellulose determination were interference by the high protein content inherent in sewage sludges and interference by iron complexes occurring naturally or introduced as conditioning agents during processing.

Protein interference can be eliminated by preliminary treatment with caustic soda before addition of the Schweitzer reagent. Preliminary treatment with hydrochloric acid removes the interference by iron compounds.

In order to obtain a sufficient quantity of solids from raw and settled sewages it is often necessary to process as much as 10 gal of the material. The use of a high-speed centrifuge, operating at 50,000 rpm and exerting a force of 62,000 G, eliminated long and tedious filtration. The centrifuge is the key instrument which made possible the analysis of raw and settled sewage.

It decreased very significantly the time required for analyses and made possible the analysis of the large number of samples required for this study.

Method

1. General discussion

The determination of cellulose depends on its reaction with cupric hydroxide in alkaline solution to form copper complexes from which it can be precipitated with dilute acids or alcohol.

2. Reagents

2.1. Schweitzer reagent. Add 11 g of cupric hydroxide to 4 lb (1,816 g) of 29-per cent ammonium hydroxide, C.P. Shake on mechanical shaker for ½ hr. 100 ml of the reagent will dissolve 0.5 g of cellulose (as filter paper).

2.2. Concentrated sodium hydroxide 50 per cent. Dissolve 500 g of NaOH in distilled water and dilute to 1 l.

2.3. Alcohol solution. 80-per cent ethyl alcohol (Solox).

2.4. Hydrochloric acid, conc. 35- to 38-per cent HCl, C.P.

2.5. Hydrochloric acid, 1.25 per cent. Dilute 12.5 ml HCl (35- to 38-per cent) to 1 l with distilled water.

2.6. Antifoaming agent. Dilute Armour Defoamer RD-2935-R in proportion of 1 part defoamer to 5 parts water.

3. Procedure for return activated sludge and mixed liquor suspended solids

3.1. Determine total solids on representative sample of sludge.

3.2. Measure out an aliquot containing approximately 0.1 to 0.3 g of cellulose into a 500-ml iodine flask (Pyrex No. 5400) and dilute to 200 ml.

3.3. Add 1.25 ml of 50-per cent NaOH and 5 ml of antifoam.

3.4. Boil for ½ hr using reflux condenser to prevent loss of solution.

3.5. Cool, transfer to centrifuge bottle (Pyrex No. 1280, 500 ml), add 300 to 400 ml distilled water, and centrifuge for 20 min at 1,800 rpm.

3.6. Decant. Wash with 300 to 400 ml distilled water (breaking up solids with policeman), and centrifuge again.

3.7. Decant. Add 100 ml Schweitzer reagent (breaking up solids with policeman) and shake in mechanical shaker for one hour.

3.8. Centrifuge. Decant liquor into another centrifuge bottle containing 300 ml of 80-per cent ethyl alcohol (Solox). Stir and allow to stand for ½ hr.

3.9. Centrifuge. Decant. Wash precipitate with 1.25-per cent HCl (breaking up precipitate with policeman) until the blue copper color of the precipitate has completely disappeared.

3.10. Filter on weighed bitumen crucible (Bitumen, Coors, porcelain No. 2A).

3.11. Wash precipitate with 100 ml of distilled water followed by 25 ml of alcohol.

3.12. Dry in oven at 108°C and weigh.

3.13. Ignite in muffle furnace at 600°C and weigh again.

4. Procedure for raw sewage and settled sewage

4.1. Centrifuge 5 to 10 gal of sewage in super centrifuge. Extract solids and proceed as in 3.1.

5. Modification for iron salts

5.1. Add 2 ml of conc. HCl, dilute to 200 ml. Boil for ½ hr. Centrifuge and wash. Repeat centrifuge and wash and proceed with 3.3.

6. Calculation

$$\text{Per cent cellulose} = \frac{\text{wt. dried residue} - \text{wt. ignited residue}}{\text{wt. of sample}} \times 100$$

Accuracy of the Determination

Analyses were made to determine the efficiency of cellulose recovery and reproducibility of results. Recovery of cellulose was 97.5 and 98.0 per cent in two tests, and the reproducibility was high in all duplicate tests.

Summary

1. A method was developed to accurately determine the cellulose content of sewage sludges.

2. Cellulose is degraded under aerobic conditions by sewage treatment devices.

3. Organisms responsible for aerobic degradation of cellulose are sensitive to temperature changes and are inhibited in their activity during the winter months. As the weather and sewage warm up, biological activity of these organisms increases, and the rate of cellulose degradation increases.

4. Because of reduced organism activity during winter months, heat dried activated sludge contains a high proportion of cellulosic fibers. These cause mechanical troubles as well as making the product unmarketable.

5. It is recognized that controlling the temperature of the incoming sewage in a large plant is not economical. However, the mass of organisms held in the system can be controlled.

6. Controlling the mass of organisms (MLSS) at a high level (4,000 mg/l) successfully kept the cellulose content below the value which produces a fibrous product.

7. Controlling the mass of organisms: (*a*) furnished sufficient numbers to overcome the effects of low temperature, and (*b*) retained the solids in the system longer thus providing more time for degradation.

Acknowledgment

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ORLON* MANUFACTURING WASTES TREATMENT

E. Folger Taylor, Frank T. Bodurtha, Jr., Robert F. Rocheleau, and George C. Gross

Du Pont has been aware for a long time of its responsibility to control water and air pollution at its plant sites. The company's attitude is best summarized in a resolution adopted by the Executive Committee in August 1938 which states that pollution abatement is a subject ". . . of major importance and one which should receive continuous study of the same type as is applied to safety work and fire protection." This policy has a bearing on plans for new plant construction and the development of new processes in that neither is considered complete unless it includes adequate waste disposal or treatment facilities. In executing this policy du Pont has spent or authorized $56 million at its plants for equipment and process revisions to reduce or eliminate waste and fumes. In this paper are described the situation existing at the Waynesboro, Va., plant and the measures taken to prevent the occurrence of additional pollution from the operation of a new large facility for manufacturing Orlon.

Plant Location

The Waynesboro Works (Figure 1) of E. I. du Pont de Nemours & Company is located near Waynesboro, Va., just west of the Blue Ridge Mountains, on the headwaters of South Fork of the Shenandoah River.

The works started in 1929 as a single-fiber plant manufacturing cellulose acetate. Over the years it has grown into a large manufacturing complex producing two fibers—a cellulose acetate fiber, Acele,† and acrylic fiber, Orlon.

River Data

The particular stream on which the works is located is called the South River (Figure 2). It joins the North and Middle Rivers 23 miles downstream from Waynesboro to form the South Fork of the Shenandoah River. The South River runs through the center of the City of Waynesboro and is the receiving stream for all of the domestic and industrial wastes of the community. The watershed above the plant amounts to 144 sq miles of mostly wooded, mountainous terrain. The level river bottom lands are intensively farmed.

The average discharge in the river for the period 1928–50 was 145 cfs; the 10-yr recurring 7-day minimum natural flow is 26 cfs; and the 10-yr recurring 7-day minimum flow below Waynesboro after ground-water additions is 52 cfs.

BOD and oxygen data are given in Table I.

Pollution Situation

At the time the Virginia State Water Pollution Control Act was passed in

* Du Pont's registered trademark for its acrylic fiber.

† Du Pont's registered trademark for its acetate yarn.

E. Folger Taylor and George C. Gross are staff members of the Textile Fibers Department, E. I. du Pont de Nemours & Co., Waynesboro, Va.; Frank T. Bodurtha and Robert F. Rocheleau are from the Engineering Service Division, Engineering Department of the same company, Wilmington, Del. *The paper was presented at the 33rd Annual Meeting of the Water Pollution Control Federation in Philadelphia, Pa., October 2–6, 1960.*

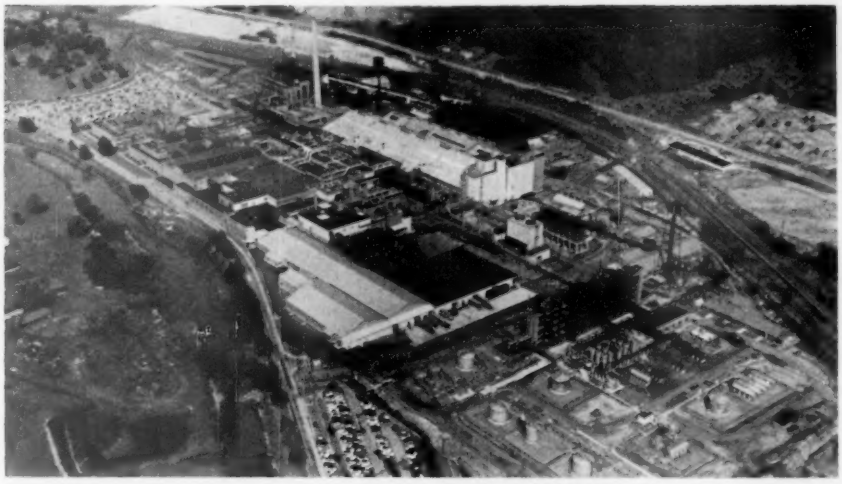

FIGURE 1.—Aerial view of Waynesboro Works.

1946, the South River below Waynesboro was grossly polluted as a result of receiving all the industrial waste and untreated domestic wastes from the entire community. In 1948 a cooperative study by the industries of the area,

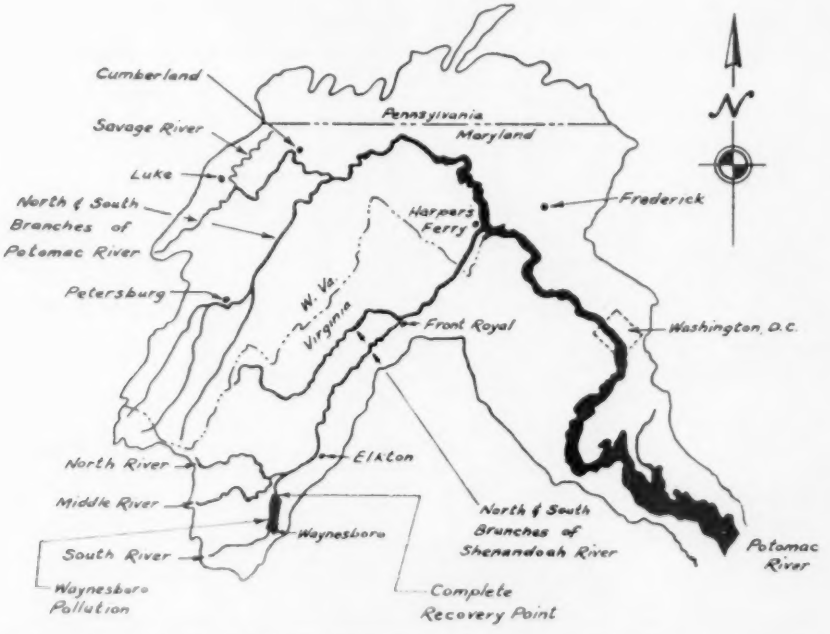

FIGURE 2.—Location of Waynesboro pollution in relation to Potomac River basin.

TABLE I.—South River Calculated Assimilative Capacity at 25°C *

Flow leaving Waynesboro (cfs, 10-yr, 7-day)	DO Content at Sag Point (mg/l)	BOD (lb/day)
52	2	4,000
52	3	3,300
138†	3	8,500
171‡	3	10,500

* Method of Churchill and Buckingham (1).
† cfs, 50 per cent of time.
‡ cfs, U.S.G.S. mean.

the City of Waynesboro, and the State of Virginia was made to determine the extent of the problem. This study showed that du Pont's BOD load to the river from the cellulose acetate manufacture, the only fiber being made at that time, averaged 13,300 lb/day and represented 70 per cent of the total community load. Since then the plant's load has been reduced by more than 75 per cent. The maximum discharge in terms of BOD now amounts to 4,000 lb/day. In 1955, concurrent with the City of Waynesboro's construction of a complete treatment plant, du Pont separated its sanitary wastes from its industrial wastes and built a connecting sewer to the city system.

The South River is now a much improved stream as a result of the efforts of the users of the river to reduce their BOD loads. However, during very dry periods the assimilative capacity of the river is too small to permit the expansion of old or building of new plants that would result in any appreciable addition to the BOD load of the river. Thus, when plans were made to construct a plant to manufacture Orlon acrylic fiber it was necessary to build extensive waste treatment facilities to meet the requirements of the Virginia State Water Control Board.

Determination of Wastes

Planning for the waste disposal facilities began with a study of the wastes occurring at the May Plant in Camden, S. C., where du Pont was already manufacturing Orlon acrylic

TABLE II.—Orlon Plant Wastes

Source	Composition	Quantity			BOD (lb/day)
		Avg (gpm)	Max (gpm)	lb/day	
Solvent recovery heads	Vapor containing 99.6% H_2O, 0.3% DMA, and 0.1% DMF	—	—	—	1,000
Acrylonitrile recovery col. tails	(a) Liquid at 107°C (b) Inorganic salts (c) Organics present as acrylonitrile, acrylonitrile reaction products	120	175	7,500	4,300
Miscellaneous wastes	(a) Liquid at ambient temperature (b) Inorganic salts (c) Organics present as dimethylformamide, dimethylamine, formic acid, acrylonitrile, finish solution	120 55	175 200	1,500 —	— 700

fiber. The major sources of wastes, the waste loads and characteristics determined by the study are given in Table II.

The dimethylamine in the solvent recovery heads is an odoriferous compound having the characteristic fishy smell of amines. Its threshold odor has been determined to be 0.6 ppm by weight.

After considering alternative methods of disposal the choice was made to develop a method to destroy completely the organics in the solvent recovery heads, to eliminate any possibility of air pollution as well as its BOD potential, and to investigate treatment of the remainder of the wastes by a biochemical oxidation process.

Disposal by Catalytic Combustion

The solution to the heads odor and BOD problem was achieved by a combination of direct and catalytic combustion (2). In catalytic combustion the organics in the heads are oxidized in the presence of a catalyst at temperatures below the auto-ignition temperature and in concentration less than the lower explosive limit. The initial experimentation was on a small unit which used a platinum catalyst suspended on inert wires (3). These experiments proved that the organics in the heads could be oxidized successfully at catalyst temperature of about 300°C, so a larger test unit was used to develop more complete data. Typ-

TABLE III.—Typical Column Heads Combustion Data

Combustion Type	Temp. (°C)	DMA (ppm/wt)			Red. (%)
		Entering Heads	Cond. Heads	Cond. of Catalyst Exhaust Gases	
Direct	335	2,600	400	—	85
	438	2,800	800	—	72
Dir. and catalytic	27	2,700	—	6.0	99.8
	29	2,690	—	4.0	99.8
	32	2,800	—	10.0	99.6

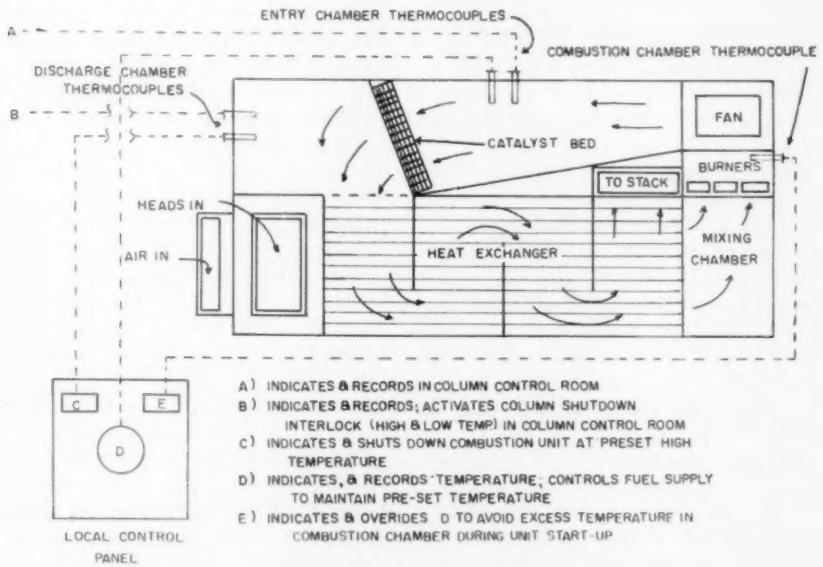
ENTRY CHAMBER THERMOCOUPLES
A
COMBUSTION CHAMBER THERMOCOUPLE
DISCHARGE CHAMBER THERMOCOUPLES
B
FAN
CATALYST BED
BURNERS
TO STACK
HEADS IN
AIR IN
HEAT EXCHANGER
MIXING CHAMBER
C
E
D
LOCAL CONTROL PANEL
A) INDICATES & RECORDS IN COLUMN CONTROL ROOM
B) INDICATES & RECORDS; ACTIVATES COLUMN SHUTDOWN INTERLOCK (HIGH & LOW TEMP) IN COLUMN CONTROL ROOM
C) INDICATES & SHUTS DOWN COMBUSTION UNIT AT PRESET HIGH TEMPERATURE
D) INDICATES, & RECORDS TEMPERATURE; CONTROLS FUEL SUPPLY TO MAINTAIN PRE-SET TEMPERATURE
E) INDICATES & OVERIDES D TO AVOID EXCESS TEMPERATURE IN COMBUSTION CHAMBER DURING UNIT START-UP

FIGURE 3.—Schematic plan of commercial catalytic combustion installation.

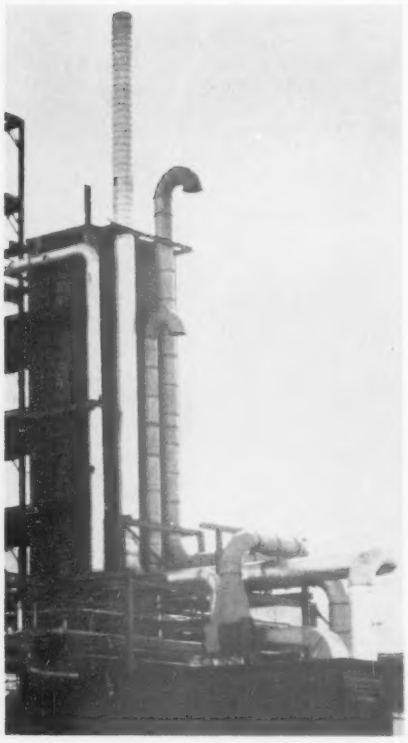

FIGURE 4.—Catalytic combustion installation.

ical combustion data are given in Table III.

The reduction of DMA to less than 10 ppm by weight requires 5 to 6 times the stoichiometric quantity of air needed for combustion. Calculations showed that by discharging the combustion products from a 90-ft stack the concentration of DMA would be reduced below the threshold odor concentration. The commercial installation, therefore, was designed with a 100-ft stack.

Figure 3 is a schematic diagram of the commercial installation. A mixture of combustion air and heads is passed through a heat exchanger into a mixing chamber and thence across the direct combustion unit. The gases at about 310°C are then forced through the catalyst bed, where a temperature rise of about 5°C normally occurs.

The hot gases then pass over the heat exchanger tubes, giving up heat to the entering gases, and are discharged through the stack. Control of the unit and safety of operations are achieved by a system of thermocouples. If the temperature goes either too high or too low, both the catalytic combustion unit and the distillation column are shut down automatically. In shutting down the distillation column the feed is cut off, heat to the column is shut off, and the water supply to the condenser is opened wide.

Figure 4 is an outside view of the commercial unit with its 100-ft stack. This unit has operated successfully for more than two years using the original catalyst and has achieved the objective of burning the organics in the heads without creating an odor or a BOD problem.

Disposal by Biochemical Oxidation

On the basis of the studies at the May plant it was planned to treat about 5,000 lb BOD/day by a biochemical oxidation process. Because time did not permit extensive study of all waste treatment possibilities it was decided to investigate specifically the feasibility of an activated sludge waste treatment plant. From the study it was shown that the wastes were treatable by an activated sludge process and the optimum pH and waste concentration were established to maintain the biochemical reaction at the maximum rate.

A relationship was established between BOD reduction efficiency and organic loadings of the aeration tank; the effects of greater than normal amounts of acrylonitrile, dimethylformamide, and finish were investigated. The studies showed the following:

1. The wastes contained a large excess of nitrogen. The BOD to N ratio was found to be about 6 to 1. This pointed to the possibility that sludge settling problems might be encountered in the sludge settling step due to denitrification (4) (5) (6).

2. The wastes became increasingly acid during the course of oxidation, requiring the addition of lime to the system (7).

3. Supplemental nutrients in the form of phosphoric acid and trace minerals would have to be provided.

Data on oxygen requirements, sludge production, and temperature effects were not determined. Normally such a laboratory study serves as a basis of design for a waste treatment pilot plant. In this instance, however, the final design was based on the laboratory studies whenever pertinent data were available, and when not available was based on information obtained from the literature or from the engineers' best judgment. The experimental studies began in late August 1956. Completion of the construction of the waste treatment plant was scheduled for December 1957.

The high temperature of the wastes offered the possibility of obtaining higher organic waste loadings per unit volume of aeration tank for a given degree of waste reduction (8). Published studies on the temperature effect on the activated sludge process indicated that maximum biological activity usually occurs between 86°F and 104°F. Sawyer and Bradney (6) indicated that increased temperatures aggravated the sludge settling problem when high nitrogen wastes were involved; however, the effects of temperatures above 75°F on denitrification had not been explored. It was decided that the advantages of operating at elevated temperatures outweighed the disadvantages, so for plant design an allowable temperature range of 85°F to 95°F was prescribed.

Because of the limited scope of the development work, a reasonable margin of safety had to be incorporated in plant design to insure that higher plant waste BOD loadings than anticipated from waste estimates at the May plant could be handled if need be, and to provide some cushion for the many process unknowns. Sufficient air was provided to satisfy a BOD loading about 25 per cent higher than that expected and a safety factor of about 40 per cent was provided in clarifier design.

The aeration tanks were sized strictly on the basis of the experimental organic loading studies. These data were secured at room temperature. The higher waste loadings that could be obtained at the higher design operating temperatures were considered to be an adequate safety factor.

Because of high salts concentration in the waste, concrete was not considered to be a satisfactory construction material due to severe corrosion problems; hence, the initial idea of using conventional long, narrow, flow-through-type aeration units made of concrete was abandoned. Corrosion studies and cost comparisons of various materials led

TABLE IV.—Design Criteria for Activated Sludge Plant

Item	Design Criteria
General	
Raw waste flow	252,000 gpd
Raw waste BOD	5,000 lb/day
Dilution water flow	504,000 gpd
Temperature	85–95°F
Aeration Tank	
BOD loading	0.4 lb/day/lb MLSS
MLSS concentration	3,000 ppm
O_2 uptake rate	24 mg/hr/gr MLSS
Clarifier	
Surface overflow	540 gpd/sq ft
Detention time	2 hr
Return sludge flow	10–50% of raw waste and dilution water

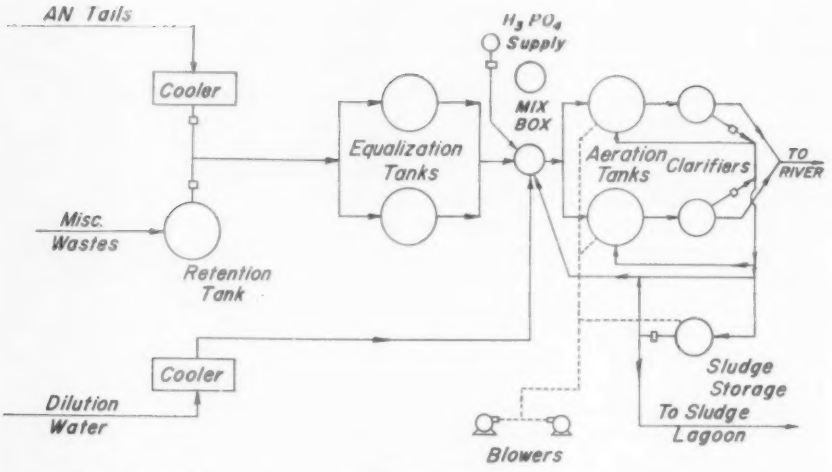

FIGURE 5.—Schematic of Waynesboro Works Orlon waste treatment flow.

to the selection of round, Hypalon*-lined, steel tanks equipped with turbine aerators, which provided for a homogeneous sludge-waste mixture. These units had been piloted but had never been used in a full-scale activated sludge plant. The final plant layout was made to provide easily for future expansion.

The design criteria on which the plant size was based are given in Table IV.

Description of Activated Sludge Plant

A flow diagram of the activated sludge plant is shown in Figure 5.

The acrylonitrile recovery column tailwaters, which contain the bulk of the plant BOD and are 107°C, are cooled to 30°C to 35°C in a wooden cooling tower before discharging to two equalization tanks, which level out variations in waste flow and characteristics.

The miscellaneous process wastes, which have widely varying flow and composition, are discharged to a separate tank for blending before being pumped to the equalization tanks for final blending with acrylonitrile recovery column tailwaters ahead of processing.

The waste mixture from the equalization tanks goes to the process at a relatively constant flow rate.

At the mix tank, process wastes, dilution water for final temperature and waste concentration adjustment, and phosphoric acid nutrient are thoroughly mixed. The original design provided for the return seed sludge to be returned to the mix box; however, after operations started piping changes were made to return the sludge directly to the aeration tanks to avoid temperature shocks.

The source of dilution water for final temperature and waste concentration adjustment is 65°C condenser water from acetate plant manufacturing operations. For plant design this was the only available source of water. A second cooling tower had to be provided to reduce the temperature of this stream going to the mix box.

From the mix box, the prepared wastes flow by gravity to the aeration

* Du Pont's registered trademark for its synthetic rubber.

tanks and then to the clarifier. The piping is such that the plant can be operated in parallel, series, or two-stage.

Clarifier overflow is normally discharged to the river. Pumps have been provided, however, to recirculate the effluent back to the mix box.

Excess sludge goes to an aerated sludge storage tank. This acts as a reservoir of fully acclimated seed sludge which can be used to reseed the main aeration tanks in the event that process upset kills the microorganisms in the aeration tanks.

The sludge from the sludge storage tank goes periodically to an earthen lagoon. The supernatant liquor from the lagoon is pumped back to process. Design plans contemplated that the sludge would be removed periodically from the lagoon. Final disposition would be spraying on plowed ground on company-owned property.

Figure 6 is a cross-sectional diagram of the main plant units. The two main equalization tanks are 63,000-gal stainless steel tanks. These provide for 12-hr retention for total wastes. The impounding tank for miscellaneous wastes is a 90,000-gal mild steel unit with an extra allowance for corrosion. This provides 24-hr retention for miscellaneous wastes. The mix tank is a 1,400-gal Hypalon-lined tank equipped with a mixer.

Each of the aeration tanks is 50 ft in diameter, 20 ft high, and of 250,000-gal capacity, and lined with Hypalon. Each is equipped with three 25-hp turbine agitators running at a speed of 120 rpm. Air supplied by an external blower is discharged beneath the rotating blades of the turbine impellers. The turbine aerators were designed to transfer 8,000 lb O_2/day for the combined tanks.

The clarifiers also are Hypalon-lined. Each clarifier is 30 ft in diameter and about 9 ft deep, providing a theoretical retention of about 2 hr at design flow conditions.

The return sludge pumps have a variable capacity from 10 to 50 per cent of the design flow. The sludge storage tank is also equipped with one 30-hp turbine aerator.

Air for the aeration tanks and the sludge storage tank is provided by one 1,500-cfm blower at 10 psig.

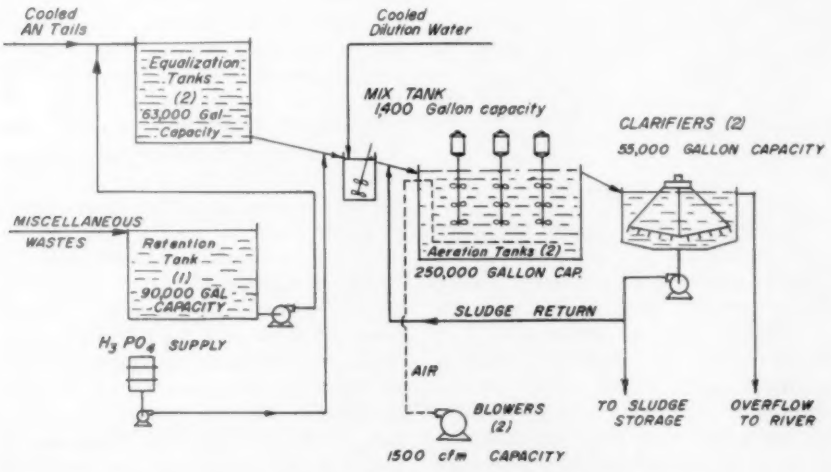

FIGURE 6.—Schematic of Orlon waste treatment flow.

FIGURE 7.—Orlon waste treatment plant.

Plant instrumentation for measuring process waste flows and temperatures, and tank levels, is fairly complete. A central instrument panel was not provided and no automatic control features are included in plant design. A plant operator logs all indicating instruments and replaces charts on recording instruments on a routine tour basis. When needed, lime is added by hand from 50-lb bags directly to the aeration tanks.

Figure 7 is an aerial view of the completed plant.

Plant Start-Up

Start-up of this plant presented some interesting problems, because an unusual restriction had been placed on the over-all start-up of the Orlon-manufacturing plant with regard to its wastes. This was that no BOD-containing process wastes would be discharged to the river except through the waste treatment plant and that the waste treatment plant would have to be fully operational by the time the first pound of waste was produced in the manufacture of Orlon. Therefore, the waste treatment plant would have to be started using a synthetic feed of simulated AN tails, dimethylformamide, and finish materials under carefully controlled conditions.

Using an 18-day program recommended by the consultant, the system was successfully started. The recommended procedure was essentially a large scale-up of the method used by Symons *et al.* (9) in studying the treatability of industrial wastes. The key to the start-up was to use trickling filter humus from the Waynesboro sewage treatment plant and sodium acetate as a supplemental feed.

In addition, seed from the Wateree River in Camden, S. C., which was already adapted to the wastes coming from the May plant for manufacturing Orlon, was cultured on synthetic feed and added to the system in the ratio of one part of cultured seed to four parts of trickling filter humus. This assured that some adapted organism would be present from the beginning.

Large amounts (up to 2,000 lb of BOD) of sodium acetate were used initially with small amounts of acrylic wastes. Over the 16-day period the sodium acetate was gradually replaced by increasing amounts of synthetic acrylic waste. At the end of this time the No. 1 aeration tank was at the design loading of 2,500 lb BOD/day of acrylic waste alone. The No. 2 aeration tank was started in 10 days by a similar procedure using sludge from the No. 1 aeration tank as seed. Figure 8 shows the course of the start-up.

Operating Problems

The waste treatment plant has been in continuous operation since March 1958. As might be expected, a number of operating problems have been encountered.

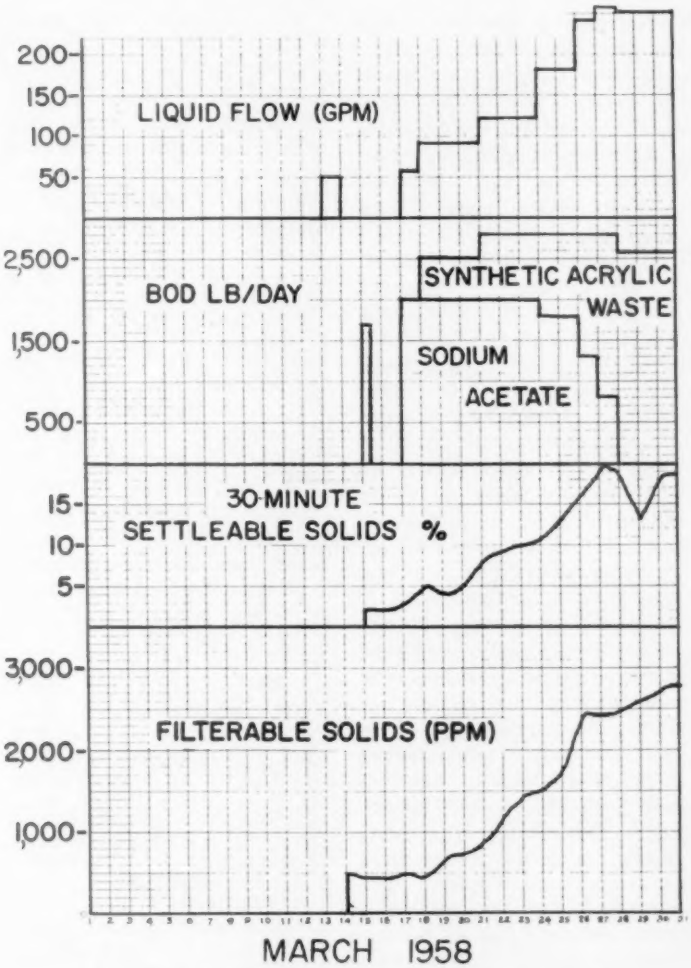

FIGURE 8.—Start-up data for No. 1 aeration system.

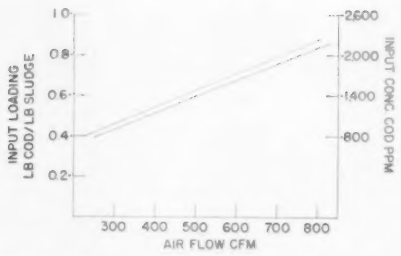

FIGURE 9.—Input loading vs. air flow for 0.2 to 1.0 mg/l DO.

During start-up it was found that the waste flow did not split equally between the two aeration systems in parallel operation. Due to the resulting unbalance in hydraulic and organic loading, entirely different biological regimes existed in each of the aeration systems. Each system presented its own peculiar problems in BOD oxidation, sludge growth, and sludge settleability. Thus, instead of having one waste treatment plant to contend with, operator attention had to be directed to two dissimilar plants. When one system was working well, the other would be out of control, and vice versa.

Initially, this problem was remedied by installing two V-notch weirs in each clarifier launder and adjusting valves in the influent feed lines to effect an equal split. Later, a pump was installed to pump wastes from the mix box to one aeration system equal to that flowing by gravity from the mix box to the other system. Sufficient head was not available for installation of a flow-splitter box.

One of the most persistent problems encountered was heavy froth formation. A frothing problem was not anticipated from the limited laboratory studies. Several types of spray nozzles using recycled effluent were tried, but were not effective. The sprays soon plugged and the froth was too stable to be beaten down by the small volume of effluent used.

Kerosene and several types of proprietary antifoamants were tried without success. Finally, oleic acid was found to be effective. Oleic acid fed directly to the aeration tanks gave good control at dosages of 15 to 30 mg/l. This agent was comparatively expensive and after treatment plant operation became more routine efforts were directed toward finding a cheaper substitute material. Currently, diesel fuel or a mixture of diesel fuel and mineral oil is being used. This is applied directly to each aeration tank.

Denitrification, with its attendant sludge rising problems in the final clarifier, has been controlled by maintaining the dissolved oxygen level in the aeration tanks in the range of 0.2 to 1.0 mg/l and by recycling return sludge at a high rate. Figure 9 shows the range of air flows that have been found to maintain the dissolved oxygen in the aeration tank at the desired level when the input COD concentration and the ratio of pounds of COD input per pound of volatile MLSS are at the level indicated. Of course, denitrification has occurred. When this happens the feed to the system is shut off, the air supply to the aeration tanks is cut back or even shut off, and the settling tank overflow and underflow are recirculated until all the nitrate has been reduced. After this occurs, normal plant operations are resumed.

Despite some anxious moments during plant start-up and periodic dif-

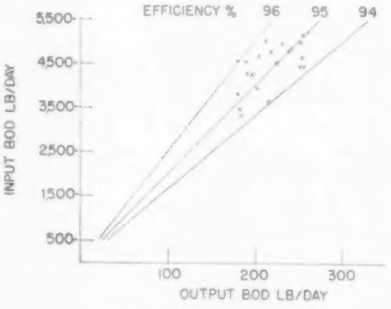

FIGURE 10.—Plant performance.

ficulties with sludge rising problems, plant operation has been eminently successful. At a loading of 5,000 to 7,000 lb BOD/day, the plant is effecting a BOD reduction in the range of 90 to 95 per cent. Figure 10 shows the BOD reduction efficiency achieved under normal operating loads.

Particularly gratifying is the response of this homogeneous-type aeration system to radical variations in temperature, feed loadings, and pH. Intentional temperature increases of 2°C/hr have been made with no visible adverse effects. Starvation periods of a week were found to have little effect on the ability of the system to assimilate acrylic wastes when the feed was resumed.

The system has been exposed to pH's from 4.5 to 10.5 for periods of 8 to 12 hr without loss of the sludge. Undesirable effects at these extreme pH's were loss of protozoa and a drop in BOD reduction efficiency. However, within 24 hr efficiency returned to normal (90 to 95 per cent).

At a BOD design loading of 5,000 lb/day, plant performance tests have shown that the oxygen transfer efficiency of the turbine aerators is about 35 per cent and the total power required (turbines plus blowers) is 0.30 kwhr/lb O_2 dissolved. Thus, the total power requirements compare favorably with the more conventional aeration devices used in other treatment plants.

Recently a material balance was made on the system covering a period of a month. With the system operating at 35 to 37°C, and at the design loading the sludge growth was about 0.4 lb per lb of 5-day BOD applied.

Summary

In building and operating a plant to manufacture Orlon acrylic fiber at Waynesboro, Va., du Pont has demonstrated that by careful planning and operating, excessive discharges of organic industrial wastes and the resulting pollution problems can be controlled to meet the needs of the location. Disposal of organic wastes by catalytic combustion and biochemical oxidation methods has reduced the pollution potential of the process from 6,000 to less than 500 lb BOD/day. It was thus possible to manufacture Orlon acrylic fiber at a site which otherwise would have been unsuitable.

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DISCUSSION

James I. Otis

To relate du Pont's waste discharges with other wastes discharges to the South River in the Waynesboro area, it might be well to discuss briefly these other sources.

A textile finishing plant discharges approximately 2,000 lb BOD/day directly across the river from the du Pont plant. Over a period of years this plant, through in-process reductions, has reduced substantially its loading to South River. However, the exact degree to which it has done so is obscured by the fact that this company's early analytical data are found to be inadequate. Approximately one mile downstream from these sources the City of Waynesboro, with a population of 12,000, discharges effluent from a secondary sewage treatment plant which achieves upwards of 90-per cent BOD reduction. Although the industries and the municipality have made admirable records regarding pollution abatement, it is apparent that there is approximately twice the BOD loading to South River that can be assimilated during periods of low flows and leave satisfactory levels of dissolved oxygen. The author has given calculated assimilative capacities for various river flows using the Churchill-Buckingham method. Other methods are slightly less optimistic in their predictions.

The Virginia State Water Control Law differentiates between those industries which were in existence when the law went into effect in 1946 and those industries which subsequently opened in Virginia or expanded their operations or employed a new process. While the opening of a new industry does not come under the same section of the law as that dealing with new processes or expanded operations, the treatment accorded them is essentially the same.

An existing industry must be issued a certificate to continue waste discharges for an indefinite period subject to any pollution resulting from the discharge being abated in accordance with decisions made by the Board, but a new or expanded industry must, prior to starting operation, provide adequate treatment facilities. In the case of the Waynesboro area, the only new process was du Pont's Orlon manufacturing operation. Its acetate operation, as well as the neighboring textile plant, were existing operations under the law.

The Water Control Board has been in the process of trying to reduce waste loading in this area to the point where satisfactory levels of dissolved oxygen will be maintained. However, the law contemplates that the Board make no requirements in regard to existing industries which are not feasible and practicable of attainment, and the Board has scrupulously observed this provision.

The Board's staff has been negotiating with both du Pont and the textile finishing industry with the ultimate aim that the combined BOD waste loading of 3,000 lb/day from du Pont and 2,000 lb/day from the other industry may be reduced to a combined total of 2,000 lb/day. It is realized that this presents some difficulties, inasmuch as du Pont's acetate operation discharges a very high volume of wastes with a concentration of only 30 to 40 mg/l BOD. It is possible that the ultimate objective cannot be

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The Discussion followed the paper at the meeting presentation.

achieved without undue hardship on the industries involved. The staff has asked the industries to supply it with technical data to show the best they can do toward achieving the objective. The results are anticipated in the near future. On the basis of evaluation of these data the staff will make its technical recommendations to the Board for appropriate action.

In relation to du Pont's Orlon operation, the Water Control Board's staff is highly gratified with the competent manner in which the company evaluated, designed, and constructed facilities for waste treatment in order that adequate treatment would be provided from the instant this process went into operation. This is the first instance in Virginia where a synthetic feed was used to start and establish treatment processes prior to the receipt of production wastes. It has been interesting to note that the company has used turbines as their means of aeration. There are two other industries in Virginia using this means. One is a large pulp and paper mill, the other a manufacturer of pharmaceuticals. However, this form of aeration device was employed subsequent to other methods of biological oxidation.

TRAINING COURSES

The following table lists coming short courses offered by various divisions of the Public Health Service and which are of particular interest to those in water pollution control. For further information contact Chief, Training Program, Robert A. Taft Sanitary Engineering Center, 4676 Columbia Parkway, Cincinnati 26, Ohio; or a Public Health Service regional office.

Date	Course Title	Location*
Oct. 16–27	Plankton Identification and Control	SEC
Oct. 23–Nov. 3	Basic Radiological Health	Rockville
Nov. 6–10	Radioactive Pollutants in Water	SEC
Dec. 4–15	Chemical Analyses for Water Quality	SEC
Jan. 15–26	Basic Radiological Health	SEC
Jan. 22–Feb. 2	Bio-oxidation of Industrial Wastes	SEC
Feb. 5–9	Recent Developments in Water Bacteriology	SEC
Feb. 5–9	Radioactive Pollutants in Water	SEC
Feb. 12–16	Radionuclides in Water	SEC
Feb. 26–Mar. 9	Water Quality Management	SEC
Mar. 12–23	Sanitary Engineering Aspects of Nuclear Energy	SEC

* SEC is the Robert A. Taft Sanitary Engineering Center; Rockville is the Radiological Health Laboratory in Rockville, Md.

LARGE-SCALE PRODUCTION OF YEAST IN WHEY

Aaron E. Wasserman, James W. Hampson, and N. F. Alvare

Cheese whey can cause a water pollution problem if disposed of as a dairy waste. The whey may be utilized, however, as a base for a medium on which yeast will grow. The yeast, containing about 50 per cent protein, vitamins, and other nutritional factors, may be used in the manufacture of animal feeds. The market for a yeast product can be expanded through increased uses of dried yeast in human diets. Previous methods for growing yeast on whey have proved economically unfeasible. A more efficient process for the production of maximum yields of yeast has been described (1). A four-hour yeast growth cycle was developed for batch operations by providing optimum conditions of available oxygen, pH, temperature, inoculum, and medium supplements. Unpasteurized whey can also be used in the medium, which effects a reduction in the cost of producing the yeast.

Preliminary studies were successfully carried out in 500 ml and 15 l propagators in the laboratory. The economic practicality of the yeast production process can be evaluated only by growing the yeast on a large-scale operation. This paper presents the results of propagating yeast in 750-gal volumes and gives an estimate of the cost of operating a yeast plant producing 2.5 tons dried yeast per day.

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Materials and Methods

Propagation Conditions

The conditions for the growth of the yeast, *Saccharomyces fragilis*, are based on those previously described for the laboratory propagators (1) (2). Six hundred gallons of Italian cheese whey, supplemented with 28 lb each of commercial grade ammonium sulfate, monobasic potassium phosphate, and dried brewers yeast, were placed in the propagation tank. The pH of this mixture ranges from 5.5 to 5.7 without further adjustment which is the optimum range for yeast growth. The whey medium was inoculated with 150 gal of yeast cream containing 110 lb yeast on a dry weight basis. The yeast in the inoculum was approximately 20 hr old, having been collected from a propagation on the previous day. It is also possible to build up the required inoculum from a smaller quantity of yeast using less medium and increasing the volume as yeast growth occurs. This method requires more time and it is more convenient when batches of yeast are in continuous operation.

The propagation was carried out at 94°F plus or minus 1° which was maintained by circulating cold water through cooling coils in the tank. Good growth of the yeast can be obtained at temperatures as high as 105°F but this procedure is not recommended because a growth of a rod-shaped bacterium contaminated the yeast.

Oxygen Requirements

The oxygen requirements for the growth of *Saccharomyces fragilis* have been described in previous studies (2)

(3). The oxygen is used to oxidize approximately 35 per cent of the carbon in lactose to CO_2 and water, and provide the energy for the assimilation of the remaining 65 per cent of the sugar. Additional oxygen is needed for the oxidation of the other organic components in the whey and for the endogenous metabolism of the yeast. Thus, the yeast growing in the 750 gal of suspension requires 90 lb of oxygen to oxidize the 240 lb of lactose and approximately 30 lb of oxygen for yeast metabolism and other oxidative purposes. The total oxygen, 0.5 lb of oxygen per lb of sugar, must be furnished during the four-hour propagation period. The addition of equal increments of 30 lb O_2 per hour will not necessarily supply the proper quantities of oxygen to the growing yeast. It has been shown (2) (3) that *S. fragilis* growing in whey medium under the described conditions requires increasing quantities of O_2 during the first 90 to 120 min of growth, reaches a peak rate of oxygen consumption and in the final stages of growth, requires O_2 at a decreasing rate. At the peak of the oxygen demand, the yeast uses the gas at the rate of approximately 5 millimoles/l/min (19 millimoles/gpm), and to supply this demand, oxygen must be dissolved at the rate of 1 lb/min. The equal oxygen increments of 30 lb/hr, or 0.5 lb/min will supply an excess of oxygen during portions of the yeast growth curve, but there will be a condition of limited anaerobiosis during the period of peak oxygen demand. Lowered yeast yields may result because of this period of insufficient available oxygen.

Apparatus

A steel storage tank 5 ft in diameter and 12 ft 8 in. in height was converted into a yeast propagator. The agitation unit, suspended from the top of the tank, extended to within 3 ft of the bottom. The agitator was a 6-vaned turbine, 23 in. in diam, powered by a 7½ hp motor. The turbine rotated at 300 rpm. In operation, the power supplied by the motor was inadequate, but a more powerful motor could not be used because of the difficulties that developed in confining the medium to the tank. Although the tank would contain 1,600 gal, only about 800 gal of medium could be used for the propagation of the yeast; the remaining 50 per cent of the tank capacity was required as head space for the increased volume of the medium emulsion created by the aeration and agitation.

Air was supplied to the medium by a turbo-compressor rated at 360 cfm at 5 psi. A sparger ring with jet orifices was positioned under the agitator turbine so the fine air streams would be dispersed still further by the shearing action of the agitator.

The temperature of the propagation mixture was controlled by passing cold water at 40°F through 118 ft of 1½ in. OD copper tubing arranged in a coil within the tank.

At the end of the four-hour propagation period, the yeast was concentrated to a slurry containing 15 to 18 per cent solids in a centrifuge-type separator. To remove extraneous soluble solids, the yeast cream may be washed by resuspension in an equal volume of water and centrifuged again in the separator. The yeast cream was fed to a double drum drier operated at 85 psi steam pressure, and rotating at 12 rpm; the dried yeast flakes were carried by worm conveyor to a hammer mill, then to a bagging apparatus.

Analytical Determinations

Yeast yields were determined as the weight of the yeast centrifuged from 5-ml samples of the propagation mixture and dried overnight at 220°F. The method of Stiles *et al.* (4) was used for the analysis of the lactose in the medium.

The oxygen absorption rate (OAR)

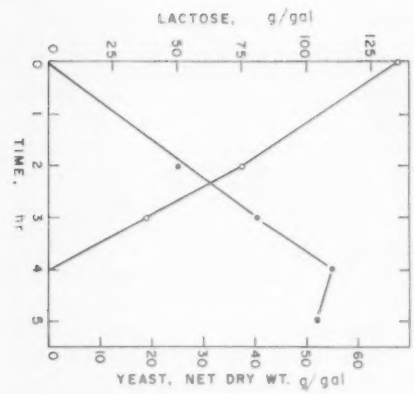

FIGURE 1.—Yeast propagation.

of the propagation apparatus was determined by a modification of the sulfite method of Cooper *et al.* (5).

Results

OAR of the Apparatus

Inasmuch as oxygen was shown to be the limiting factor in obtaining maximum yields of yeast in the laboratory, using the procedure described above, the agitation and aeration systems for the pilot plant tank were designed to dissolve the required amount of the gas. To test the operating efficiency of the equipment, 800 gal of 1N sodium sulfite solution were agitated in the propagator with the blades of the turbine set at 25 in. diam. Aeration was carried out at 360 cfm. The OAR under these conditions was 13 millimoles/gpm. Since the yeast requires 19 millimoles O_2/gpm at the peak demand, the apparatus was capable of dissolving only 68 per cent of the requisite amount of gas. To increase the quantity of dissolved gas, the tank was altered by the installation of four steel baffles, 90 in. long and 8 in. wide attached to the walls of the tank. In addition, the diam of the turbine blades was reduced to 23 in., increasing the peripheral speed of the blades and obtaining a greater shearing effect on the air bubbles. As a result of these changes, the OAR rose to 15 millimoles O_2/gpm, or 80 per cent of the O_2 requirements of the yeast. Although the rate of O_2 solution was still apparently low, further modification of the propagator was not possible and growth of the yeast was carried out with the knowledge that decreased yields might occur.

TABLE I.—Representative Growth of *Saccharomyces Fragilis* in Whey Medium

Item	Amount
Volume whey (gal)	600
Lactose (4.86% of whey) (lb)	242
Lactose used (lb)	242
Volume seed yeast (gal)	150
Wt. seed yeast (lb)	110
Total volume in tank (gal)	750
Gross dry yeast yield (lb)	215
Net dry yeast yield (lb)	105
Theoretical yeast yield (lb)	133
Theoretical yield (%)	79

TABLE II.—Estimated Capital Costs for 2.5-ton/day Yeast Plant

Equipment	Cost
Storage tanks	$ 6,000
Fermenters	15,000
Blower-compressor	3,500
Holding tanks	5,000
Yeast separators	10,000
Drum drier	25,000
Refrigerating plant	20,000
Grinder, bagger, etc.	6,500
Building	23,000
Laboratory	9,000
Piping and auxiliary features	36,000
Total plant cost	$159,000

Yeast Propagation

The results of a representative yeast propagation are shown in Figure 1 and Table I. The 242 lb of sugar present in the 600 gal of whey disappeared in 4 hr and the initial 110 lb of seed yeast increased to 215 lb. Incubation of the yeast beyond four hours did not result in any increase in the yeast weight. In fact, since the sugar had been utilized, further growth may occur at the expense of the yeast already formed and some decrease in weight

could be anticipated. Approximately 55 per cent of the weight of the lactose is converted to new yeast material; therefore, the 242 lb of lactose should result in the formation of 133 lb of yeast matter. The 105 lb of yeast formed represents 80 per cent of the theoretical yield.

Economic Analysis

From the experiences of the pilot plant studies an estimate has been made of the cost of constructing and operating a plant growing yeast on whey. The calculations are based on a plant operating 200 days per year and producing 5,000 lb dried yeast/day. Estimated approximate equipment and installation costs are shown in Table II. These values may change with such factors as price variations, locality, and the availability of existing equipment. An estimate of $159,000 has been made for the purpose of further calculations. The estimated fixed capital costs are listed in Table III. These costs amount to 3.657 cents per pound of dried yeast produced.

TABLE III.—Annual Fixed Costs

Item	Cost
Depreciation (10%)	$15,900
Operational expense (5%)	7,950
Insurance, taxes, maintenance (8%)	12,720
Total	$36,570

Estimates of the operating costs in producing yeast from whey are shown in Table IV. The propagation medium components, acid, alkali, and defoamer that are used during yeast growth account for 1.755 cents of the cost of producing a pound of dried yeast. Steam and water, power, and labor (including the salary of a technically trained supervisor) cost 3.15 cents per pound of yeast. The drying operation, at 2.73 cents, increases the total cost of producing a pound of product to 7.715 cents. Total production costs, shown in Table V, are 11.292 cents per pound of yeast.

TABLE IV.—Estimated Labor and Material Costs of 2.5 ton/day Yeast Plant

Item	Cost (cents/lb dried yeast)
Material	
Aqua NH_3	0.038
Dried yeast	0.105
Na_3PO_4	0.012
$(NH_4)_2SO_4$	1.000
Defoamer	0.600
Services	
Steam and water	0.250
Power	1.340
Labor	1.560
Drying	2.730
Total	7.635

At the current market price of animal feed yeast, this process may provide a break-even method for disposing of whey without creating a pollution problem. This estimated cost of production can be reduced, in some cases, by crediting the cost of existing methods of whey disposal.

These figures were prepared for a yeast propagation plant operating in conjunction with a cheese manufacturing plant. No charge was made for the whey itself nor for its transportation. It may become necessary to obtain additional whey from other cheese producers and the purchase and transportation costs will increase the unit cost of the dried yeast. Under these conditions, a product suitable for human consumption can be obtained with only a little more expense in equipment and with a little more care in producing the yeast. The present market price for an edible yeast product makes the use of whey as a growth medium for yeast a profitable venture.

TABLE V.—Unit Costs of Producing a Pound of Yeast

Item	Cost (cents/lb dried yeast)
Operating cost	7.635
Fixed cost	3.657
Total	11.292

Summary

Saccharomyces fragilis, growing in a 750-gal volume of medium composed of Italian cheese whey plus growth supplements, can remove all available lactose from the medium and convert it into new yeast matter. The efficiency of the conversion of sugar to yeast is related to the supply of the proper amount of dissolved oxygen. An estimated economic analysis of the process of propagating yeast for food and feed purposes on cheese whey is presented.

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CONSTRUCTION GRANTS BY POPULATION

The following tabulation shows a breakdown of total cumulative construction grants (as of July 31, 1961) under the Federal Water Pollution Control Act:

Population	Number of Projects	Cumulative Number (per cent)	Estimated Eligible Project Cost ($)	Cumulative Est. Cost (per cent)	Federal Grant Offers Made ($)	Cumulative Grant Offers (per cent)
Less than 2,500	1,366	49	167,524,226	17	48,472,062.46	21
2,500 to 5,000	459	65	135,745,690	30	38,721,483.27	38
5,001 to 10,000	396	79	169,894,138	47	46,189,235.83	58
10,001 to 25,000	279	89	184,360,470	65	42,930,823.07	77
25,001 to 50,000	129	94	116,253,003	77	22,912,525.19	87
50,001 to 125,000	76	97	96,310,812	86	13,576,014.88	93
125,001 to 250,000	43	98	35,235,992	90	6,005,193.92	95
250,001 to 500,000	27	99	40,208,232	94	5,010,700.44	98
500,001 and over	26	100	63,936,833	100	5,387,439.22	100
Totals	2,801	—	1,009,469,396	—	229,205,505.28	—

A UNIQUE DISPOSAL SYSTEM FOR COMBINED WASTES AT HARRIMAN, TENNESSEE

Julian R. Fleming

The Problem

In the spring of 1959, the Harriman sewage disposal project was placed in operation. This successfully solved a problem that involved the discharge of municipal and industrial wastes into the Emory River and affected the public water supply of the city.

The city of Harriman, Tennessee, a town of 7,000, is located on the Emory River, a tributary of the Clinch River which flows into the Tennessee River. The town is approximately 45 miles generally west of Knoxville. A major factor that has affected Harriman's water supply is that the Emory River has a watershed that acts like a roof because the runoff is very rapid following a heavy rainfall, and a sustained stream flow is not maintained. The Emory River flow at Harriman has ranged from less than 1 cfs to an estimated maximum of 195,000 cfs.

Prior to the development of the Watts Bar steam and hydroelectric plant by the Tennessee Valley Authority in 1942, the only important problem of the public water supply was that of inadequacy in dry weather. The Watts Bar dam created an impoundment in the Clinch River and in the lower reaches of the Emory River, including that portion of the stream in the vicinity of Harriman. Although the water supply intake is some distance upstream from the municipal and industrial wastes outlets, it was found by TVA engineers that under certain conditions density currents developed in the Emory River causing pollution to flow upstream in one stratum while another layer flowed in the normal direction.

In this way domestic sewage and various types of industrial wastes, principally liquid wastes from a large neutral sulfite paper mill, flowed upstream and entered the water intake. This resulted in a heavy bacterial load being imposed on the filter plant and tastes and odors that could not be eliminated by any known type of conventional treatment.

Thus Harriman found itself in the unique and unfortunate position of polluting its own water supply, and of not being able to move the intake upstream above the embayment because of the very low dry-weather flow of the stream. Figure 1 shows the general features of the river course at Harriman, the location of the water plant, the Mead Corporation plant, the lift stations, interceptors, and other features of the new sewerage system.

For 15 yr the City of Harriman, the Mead Corporation, the state regulatory agencies, and a firm of consulting engineers considered the difficult technical problems involved and possible means of financing a system of treatment and disposal for the municipal and industrial wastes. The resulting design was financed jointly by the City of Harriman and the Mead Corporation.

In 1957 the construction contract for the project was let and operation began

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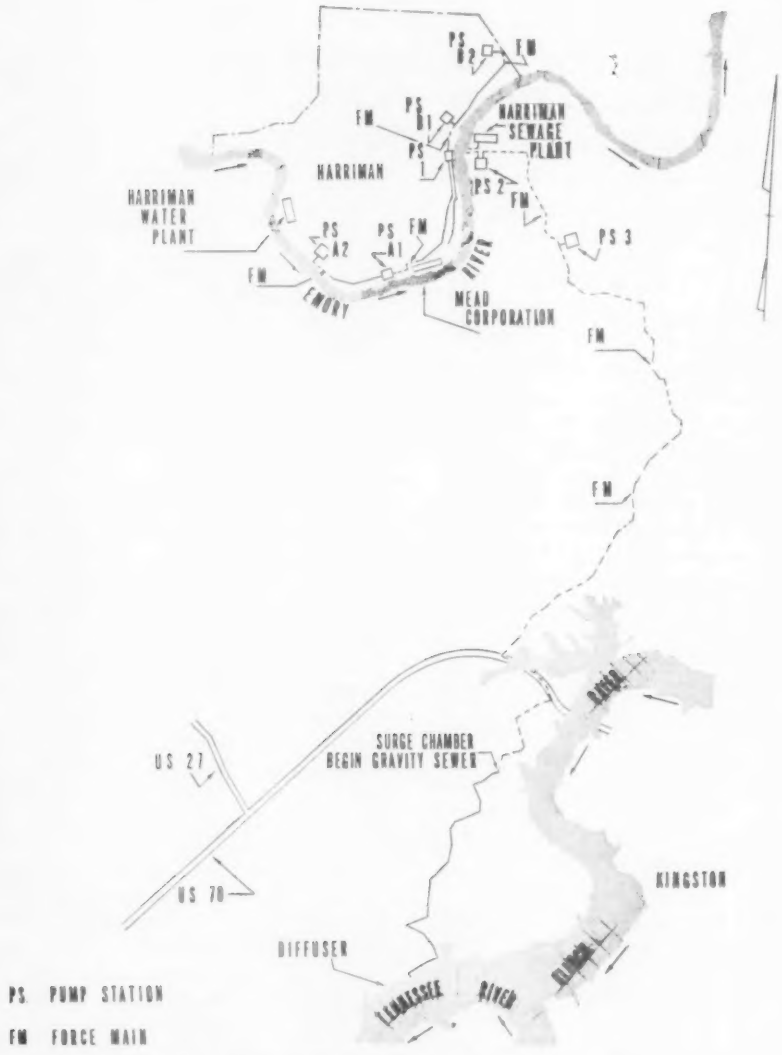

FIGURE 1.—Sewerage facilities at Harriman, Tennessee.

in the spring of 1959. Because of the technical difficulties and expense involved in complete treatment of neutral sulfite wastes, it was decided that primary treatment of domestic waste, some pre-treatment of the paper mill waste, and a long pipe line with eventual disposal in the main channel of the Tennessee River near Kingston would be used to utilize the large volume of dilution water available in the Tennessee River. Total cost of the project was approximately $1,700,000.

General Features of the Project

A system of lift stations and interceptors is used to collect the municipal

and minor industrial wastes of the city. Four small lift stations concentrate all of the domestic waste on the west bank of the river across from the treatment plant. The liquid waste from the Mead plant enters the same pumping station, which is designated as Pumping Station No. 1. This is really two pumping stations in one building, since the two types of waste pass through it entirely separated. From this station two force mains of ball joint cast iron pipe cross the Emory River. One river crossing line routes domestic sewage and miscellaneous industrial wastes to the treatment plant and the other carries the sulfite wastes to Pumping Station No. 2.

The treatment plant includes facilities for primary sedimentation, separate digestion, sludge drying beds, and chlorination of the effluent. The plant effluent is then mixed with the paper mill waste in the wet well of Pumping Station No. 2.

The pumping units of Station No. 2 are designed for an operating head of 108 ft of water. A force main 5,147 ft long and 20 in. in diameter conducts the combined wastes to Pumping Station No. 3.

From Pumping Station No. 3 a pressure line consisting of 24,731 ft of 20 in. pipe conducts the waste to a surge chamber at the high point of the pipe system. From this point the flow is by gravity and the line is constructed of 21, 24, and 30 in. vitrified clay pipe. The gravity line that completes the circuit to the bank of the Tennessee River is 8,307 ft long and terminates with 960 ft of ball joint river crossing line. The final 298 ft of the river crossing line was placed in the main channel of the river, and has 3 in. diameter holes spaced 8 ft on centers directed 30 deg below the horizontal and discharging downstream. The river crossing line is supported by precast concrete anchors located near each ball joint.

Design Problems

The major problems of design concerned the choice of material and lining for the force main from the sewage treatment plant to the surge chamber, and the choice of pumps for Stations No. 2 and 3. Each main lift station contains 3 pumps, one rated at 1,000 gpm, and two each rated at 2,100 gpm. The presence of considerable amounts of hydrogen sulfide and other corrosive materials in the combined waste prohibited the use of ordinary ferrous materials or unprotected concrete. Prestressed concrete pipe with an internal steel cylinder lined with hot spray vinyl coating was selected.

The heads were too high for the usual type of non-clog centrifugal pumps. The pumps finally selected were heavy duty vertical turbine type with bowl shafts of stainless steel and with special bearings to resist the action of hydrogen sulfide. The operating head for the pumps at Station No. 3 was to be 180 ft, and somewhat less for Station No. 2. It was decided that manual air relief valves would be more suitable than automatic relief valves. These valve assemblies were fabricated of stainless steel to resist the corrosive action expected.

Operating Problems

Soon after operations began, it was found that the surge chamber at the end of the force main acted as a chimney to vent odors similar to those from a neutral sulfite paper mill plus the familiar odor of hydrogen sulfide. The wastewater temperature approximated 110°F and hydrogen sulfide was found to be generated by the turbulence in the outfall gravity line. The first attempt to control the odors was the use of different masking agents sprayed continuously into the surge chamber through two small nozzles having a capacity of ¾ gpm each. In this manner some odor control was secured.

However, it was found that other

TABLE I.—Sewage Flow Data

Item	Quantity
BOD, influent (mg/l)	315
BOD, effluent (mg/l)	253
Average flow (mgd)	0.50
Paper mill waste, influent to Pumping Station No. 2, BOD (mg/l)	1,077
Average flow of paper mill waste (mgd)	1.7
Average flow of combined waste (mgd)	2.3
BOD—equivalent population of treated sewage	6,300
BOD—equivalent population of paper mill waste	92,000
BOD—equivalent population of combined waste to river	98,000

measures were also required and it was decided to add lime to each wastewater separately. As a result a substantial increase in pH has been achieved at Pumping Station No. 2; a drop in pH of approximately one full point usually occurs in the five hour detention period from that point to the surge chamber (3-mgd flow rate). The increase in pH very definitely reduces hydrogen sulfide generation. Recent tests have indicated the H_2S to be about 4.5 mg/cu ft as compared with former values of 800 to 1,200 observed in 1959. Odor masking compounds are now being used at the surge chamber and at Pumping Station No. 1 for further odor control. Analyses for May 1960 show the pH of the liquid at the surge tank to vary from 6.8 to 9.9, with an average of 7.9. During the same month the hydrogen sulfide content of the liquid at the surge tank showed a minimum of 0, average of 15, and maximum of 33.3 mg/l. Corresponding values for the atmosphere at the surge tank showed a minimum of 0, average of 3.2, and maximum of 16.6 mg/l.

Based on recent plant operating records, Table I shows approximate data on sewage flow, paper mill wastewater flow, and the BOD of each.

The above data include the digester liquor from the paper mill, as well as miscellaneous industrial wastes that are combined with the domestic sewage and receive primary treatment in the sewage treatment plant.

At the final discharge into the Tennessee River a 24-hr minimum flow dilution factor of 3,500 cfs, and a long-time average flow of approximately 26,000 cfs is available. Although the system appears to be functioning satisfactorily insofar as pollution of the Tennessee River is concerned, it may become necessary for the paper mill to provide additional pre-treatment. At the minimum flow in the Tennessee River, the color added to the stream does not exceed 10 mg/l, and the BOD added is approximately 1 mg/l.

Summary

The Harriman disposal project includes four small lift stations for sanitary sewage, a system of interceptors, and three main lift stations. The sanitary sewage receives primary treatment and chlorination. The wastes are then mixed, and pumped through two lift stations to a surge chamber, from which gravity flow routes the waste to a diffuser ball joint pipe line in the main channel of the Tennessee River, some 7 miles from Harriman.

Acknowledgments

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PROBLEMS OF TASTES AND ODORS

Robert A. Baker

The quality of water supplies is becoming of vital concern as demand and reuse increase. Taste and odor are properties currently receiving much attention. Present studies emphasize odor since taste is often indistinguishable from or is a function of odor. Methods of test for odor intensity and characterization vary greatly and must be improved and standardized to yield reproducible results and facilitate subsequent communication. Improvement of the methods requires a broad approach since many other factors affect the chemical and biological parameters usually considered.

The Manufacturing Chemists' Association recognizes that there is a need to examine the problem of taste and odor in water. It has also concluded that existing techniques are wholly inadequate for concerted application of remedial measures by individual companies on all problems. In light of some of the limitations of the present technology a program of study was initiated to survey present knowledge, indicate the gaps, and try to fill these by research. The results will be made available to government, municipal, industrial, and other groups.

Research Program

The program is divided into various phases. The first phase, a critical review of the literature and laboratory data, is discussed in this paper. The technical publications of the water, wastewater, and many other fields were examined and unpublished data were solicited. For example, the food industry has for many years based product improvement on subjective testing with panels of testers. Subjective testing procedures and methods of data evaluation have been developed which are applicable in a study of taste and odor in water.

Findings predating 1940 were usually omitted from consideration except where historical importance was indicated since analytical methods and over-all changes in technology make current evaluation questionable. The literature search was supplemented by site visits to selected government, industry, and university laboratories active in related research. These personal contacts proved a valuable means of exchanging information and observing testing methods.

The final report is expected to include more than 300 references. It examines such topics as physical, chemical and biological factors, methods of test, physiology and olfactory theory, chlorination practices, panel selection, and statistical evaluation of subjective data, etc.

The Problem

The consumer judges water quality by clarity, sparkle, palatability, and freedom from objectionable taste and odor. These are subjective qualities that supplement basic biological and chemical requirements. If these water properties are not acceptable to the consumer, especially those of taste and odor, complaints are initiated to the water supplier or responsible regulatory group.

Increased reuse of water resources will increase the difficulty of maintaining water quality. Additional water

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TABLE I.—Causes of Odor from 241 Water Treatment Plants

Cause	Plants	
	Number	%
Algae	198	82
Decaying vegetation	162	67
Industrial wastes	92	38
Other	55	23

treatment plants will have to be added to supplement existing facilities and to expand service to new areas. In 1954 there were 570 water treating plants serving communities with populations in excess of 25,000. Of these plants 201 serving 34 million persons had facilities for taste and odor control (1). As more persons are served and treatment becomes more difficult it may be expected that raw water quality will be more strictly controlled. This will mean stricter control of wastewaters. Better analytical methods, communication, and early-warning procedures will have to be devised.

Industrial and domestic activity, municipal effluents, and natural sources contribute odorous compounds. The complicated chemical and biological reactions taking place in the water body may result in (*a*) the production of more intense odors than those of the original constituents, (*b*) their suppression, or (*c*) total removal.

Table I shows the results of a survey of the causes of odor problems at 241 water treating plants (2).

It was reported that although algae problems were most common, the industrial wastes were more difficult to treat.

As water problems increase, additional legislative and regulatory steps to limit or control wastewater discharges may be expected. Reasonable regulations are only possible if there is a sound technical foundation. This is especially true of taste and odor criteria. At the present time there does not exist a universally-accepted method of test for these properties. Neither the intensity nor the character are defined in any consistent manner by the variety of analytical methods now used.

The chemical industry, as one of the largest groups which will be affected by legislative controls, considers it imperative to develop the necessary technology and to provide a sound basis for regulatory action.

Taste

The terms "taste and odor" are used jointly in the vernacular of water technology. The technical literature contains relatively little concerning taste of water alone. Many naturally-occurring minerals and salts impart taste to water. Some areas of this nation have water supplies with typical sulfurous or saline tastes. In excess quantities, these substances make water unpalatable. Man-made organic chemical substances may also affect taste of the water or aquatic life found in the water.

Because of the numerous studies concerning the effect of phenol on water supplies there has been evidence that this chemical will taint fish flesh. Recent investigations (3) (4) indicate that substances associated with phenol in wastewater are more important contributors to flesh-tainting than the phenol.

One of the most comprehensive analyses of the effect of a substance on taste of water was made when fluoridation was advocated for the control of dental caries (5). It was conjectured that the 1-mg/l sodium fluoride proposed would impart a taste. Extensive panel tests indicated that the probability of detection of this level of fluoride was less than 0.001. Supplemental studies at concentrations up to 18 mg/l fluoride indicated that at low (subthreshold) concentrations of salts there is an ionic effect that influences palatability.

Physiological Factors

There are many theories of olfaction which for the most part are unsubstantiated. Although elucidation of the mechanism of olfaction is not of primary concern to the water technologist there are certain physiological considerations which are important in the subjective testing of taste and odor. If ignored, these factors may seriously affect the result of threshold measurement.

Two kinds of fatigue influence persons making subjective tests. One form represents physical exhaustion or boredom associated with repetitious analyses. A second form is physiological fatigue. A tester may be desensitized by certain chemicals if exposed to critical concentrations. It is also possible to confuse the senses by background odors or too frequent exposure to a given odor. Since all these factors affect a given person and persons differ among themselves, it is logical to expect variation in threshold measurements under the best conditions and appreciable variation if background odors exist or tests are made too frequently.

The frequency with which repeat measurements may be made depends on the substance being tested and personnel variation. Experience in subjective testing, age, sex, and personal habits influence the results.

Physical Factors

Temperature and humidity affect olfactory results. Studies have been made in environmental chambers precisely controlled by complex heating, air conditioning, and humidification equipment (6) (7). It was found that (*a*) an increase in humidity at constant dry-bulb temperature tends to lower the intensity level of odor, (*b*) the effect of humidity is not the same for all odorants, (*c*) a reversal of odor perception below 70°F appeared to occur with increased humidity for pyridine and methyl salicylate, (*d*) at constant specific humidity the odor level of cigarette smoke decreases slightly with dry-bulb temperature, (*e*) olfactory adaption occurs more rapidly during initial exposure, (*f*) over extended periods, cigarette smoke has an irritating effect on the eyes and nasal passages, and (*g*) odor perception is a log function of concentration. These results were obtained in an investigation of the effect of cigarette smoke but are reported here because they typify the effect that temperature and humidity exert on olfaction.

An ideal odor laboratory should be constructed of nonabsorbing surfaces and provide temperature and humidity control. A research laboratory should provide an odor-free atmosphere by activated-carbon filtration of the air. Facilities of this nature may not be available or necessary for day-to-day testing but every effort should be made to minimize background odors.

The effect of physical parameters on odor testing merits additional investigation.

Biological Factors

Biological action is important in modifying odorous and other compounds in water. Aerobic and anaerobic processes destroy or modify these materials. They may create odorous byproducts from substances of little or no odor or modify the character and intensity of specific odorants. Given organisms may not be odorous but their metabolic byproducts or associated microorganisms may cause taste and odor problems.

Water bodies have a limited self-purification capacity through biological degradation of man-made wastes and this capacity must not be exceeded. A system of allocation of self-purification capacity of one river (8) has been developed by industrial and municipal groups.

Taste and odors of biological origin usually exhibit seasonal frequency.

Incidence of algae and actinomycetes, flushout of decaying vegetation and associated organisms, and similar problems occur at reasonably defined periods. Algae are probably the most important cause of taste and odor in water. They may not be directly responsible but are important as sources of protein for other microorganisms such as actinomycetes. The products of actinomycete metabolism include ketones, aldehydes, fatty acids, and aromatic organic compounds (9).

Chemical Factors

Chemicals may produce odor directly or by reactions with other substances. The reaction products may be more or less odorous than the original chemical. A chemical analysis therefore will not permit prediction of the intensity or character of odor in most cases but is important in identifying causes and determining treatment for taste and odor control. Analyses should be made routinely. Most water plants make tests only during times of difficulty. To avoid misleading information and conclusions, tests should be made during trouble-free periods also. Another problem is that the method of test often defines the substance. As an example, "phenol" is defined by one of many tests, none of which measure all phenolic materials.

Many attempts have been made to relate odor to molecular structure (10) (11), but the theories postulated have all been deficient. Most inorganic chemicals, except sulfur compounds, are nonodorous. Organic chemicals are the cause of most taste and odor problems. Man-made synthetic surface active materials (detergents) have been found to be unimportant as sources of taste and odor in concentrations usually found in water supplies. The perfumes contained in some detergent formulations do contribute taste and odor however (12). The effect of any of these substances may be severely modified by the presence of other substances in water.

There is a difference of response by given persons to different odor types (13). Some persons show a marked increase in acuity over others in detection of certain types of odor. This suggests the importance of calibrating panels of testers in some research work or operators making threshold measurements at industrial and water-treating plants.

Chlorine and chlorine compounds are used in treatment of taste and odors as well as destruction of pathogenic and other organisms. Some chlorode-rivatives which form during the treatment may be more undesirable as taste and odor components than the chemical being treated. Special procedures are necessary to eliminate obnoxious chloroderivatives.

Phenol

The effect of phenol, a component of many industrial wastes, on taste and odor has been a subject of many studies and some regulatory action over the last 40 yr. The present U.S. Public Health Service proposed limit is 0.001 mg/l (14) and this is based on taste and odor not toxicological considerations (15). The origin of these limits and the cause of objection to them is interesting historically and indicates the way controversy may develop with other materials. It has already been noted that analytical methods for determination of phenol vary. Consequently a variety of definitions of phenol exist, depending on the limitations of the analytical scheme. Furthermore, phenols may occur from natural sources.

During the 1920's the Public Health Service made various laboratory studies which concluded that chlorination of phenol caused objectionable chlorophenolic taste and odors if the phenol concentration exceeded 0.005 mg/l. The results of this study were used as the basis for several state and local

regulations. Some industry groups objected because of the effects of other substances present in water which serve as synergistic or antagonistic agents and specifically because the phenol taste and odor thresholds determined with various waters varied appreciably. Other factors were modifying the effect.

Most of the investigations on the phenol problem were of short-term nature until a recently completed four-year study was made of a river system in eastern Ohio and western Pennsylvania (16). The industrially supported program was closely followed by the respective state agencies. No relationship was found between phenol level and maximum odor obtained by incremental chlorination. The conclusions stated that the greater the chlorine demand the greater the odor although phenol concentration did not correlate with the chlorine demand. In one case phenol was measured on 191 of 197 consecutive days but phenolic or medicinal tastes were reported on only 25 days. These results have been questioned (17) on the basis that phenol is not found in natural waters.

The difficulties with phenol may be expected to occur with other materials in the years to come. As new products are developed and marketed, a variety of complex organic substances will find their way into water bodies. The effects of these chemicals singly and as binary and more complex mixtures with other chemical and biological substances must be determined. Standards or limits based on single components in tap or distilled water will be inadequate. A cooperative program between industry and regulatory groups will be necessary to protect water consumers.

Instrumental Devices

Although there is no substitute for the human nose as a detector of odor there have been attempts to improve or supplement olfactory detection by instrumental devices. A variety of mechanical devices which serve to prepare dilutions of samples or to exclude background odors have been suggested. None has met universal acceptance. Other instruments based on chemical or physical principles have been tried as odor detectors. Success has only been achieved when a very limited number of odor sources exist. Because of the complexity of the water chemistry and biology and the possible synergistic and antagonistic effects this is not surprising.

Odor composition research and plant control in some cases may be assisted by several recently developed analytical tools. Gas-liquid chromatography using ionization detection, long-path infrared or ultraviolet spectroscopy, and mass spectroscopy appear to be the most useful (18).

Correlation of panel-testing results and instrumental chemical analyses may provide a means of monitoring water quality in some cases. Instrumental methods are not available for continuous monitoring of all components of industrial or municipal wastes. Development of instruments and techniques is necessary.

Subjective Testing

The method of selecting persons to make taste and odor tests, the design of experiments, and subsequent evaluation of the findings is important to over-all understanding. Because of the subjective nature of the sensory tests and the variation in personal response to stimuli, calibration of individuals and estimation of precision and accuracy of testing methods are difficult.

Those research persons making taste and odor tests should be carefully selected, trained, and kept informed of progress. In plant practice, operators usually make routine threshold odor tests. They are not selected for their sensory skills but their relative sensitivity should be established to facilitate

comparison of results between different operators. There are important effects based on persons, odor type, and person-odor type interactions. Clarification of these relationships must be achieved if precision and accuracy limits are to be established for methods of test for odor. In turn, this information will establish the confidence interval at which a reasonable scale of odor intensity may be established.

Treatment Problems

For a given water supply a water-treating plant will generally have to contend with only a limited number of troublesome wastes or taste and odor-producing chemicals. Experience with these materials and recognition of seasonal influences are important. Water plants usually have difficulty with slug discharges of noxious susbtances. An early warning system to permit diversion of intake or changes in treatment procedure is desired. Ideally there should be no such occurrences but accidental discharges are always possible.

Tests of water quality, both subjective and instrumental, should be made routinely. Analyses made only during incidences of difficulty are inadequate since they do not provide a reference to normal operation. Odor control must be achieved on a local basis by cooperation between municipalities, industry, and treatment plants. Attempts to control odor by national regulations are not reasonable. The complex biological and chemical nature of the water universe precludes adoption of a single criteria for judgment and control of all water bodies. Intensity alone is an inadequate gage of odor acceptability. Some odors of very low intensity are obnoxious while others are tolerable at high intensity levels and even considered pleasant.

Industry must know and understand the role of its wastewater discharges. A given company or industry group producing similar wastes should be most acquainted with the effects of their discharge and take action if these effects are undesirable. This is ethically and economically sound and provides a basis for cooperation with responsible regulatory groups.

Activated Carbon

Activated carbon is an important and almost universally used material for treatment of taste and odor. Economic considerations preclude its use alone so it is combined with other treatment procedures.

The property of activated carbon to adsorb organic chemicals from water is the basis for a carbon filter analytical device (19) (20) (21). The carbon filter has been used to isolate the organic components of wastewater. Separations are made and individual compounds are identified. The method is valuable but has limitations. Some materials may not be recovered; there may be degradation or changes in relative composition during the lengthy sampling period; troublesome, short-duration, high concentrations are not discernible; and the taste and odor effect of compounds isolated from the filter may not be representative of the actual water. A high degree of judgment is necessary in interpreting results.

A proposal (22) has been made to control organic discharges, as determined by the carbon filter method, to less than 0.2 mg/l. The same reference (22) noted that the chloroform-soluble carbon filter extract limit is being considered for incorporation in the impending revision of the Public Health Service "Drinking Water Standards" as a recommended limit. This may prove to be a reasonable recommendation but because of the limitations briefly noted above, it appears that further study is necessary before final decision is justified.

Laboratory Study

A laboratory study of methods of test for intensity and characterization

is underway. An odor-testing laboratory with carbon-filtered, temperature- and humidity-controlled atmosphere is being used for panel testing. Among the supporting analytical tests will be gas-liquid chromatography with flame-ionization detection. This precise technique for measurement of small concentrations of gaseous components will be supplemented by infrared and visible spectrometry, and conventional wet-test chemical methods as required. It is the object of this laboratory study to establish sound foundation for measurement and interpretation of taste and odor in water. Establishment of this goal will facilitate application of these methods to field use in early warning systems and effluent quality control.

Conclusions

A program of study to develop information and analytical procedures for taste and odor in water has been undertaken by the Manufacturing Chemists' Association. The object is to provide a sound technical basis for the control of chemical plant wastewater discharges to avoid creation of taste and odor problems. The study is divided into several phases. The first phase, a critical review of the literature and laboratory findings, has recently been completed. Various gaps in the knowledge were indicated. The following unsatisfied objectives were formulated:

1. Develop an acceptable, reproducible method for measuring odor. Present methods vary and their reproducibility is unknown.

2. Determine the effects of such primary variables as odor type and concentration and their effects on each other. The control of wastewater discharge based on single chemical concentration limits is inadequate but little is known of the effect of complex mixtures.

3. Determine the effects of human factors. Odor measurement is a subjective test and complaints, control, and regulation are made by persons differing in stimuli response. Sensitivity for a given person varies as a function of time and other factors such as sex, age, physiological status, medical history, etc. The interaction of the human factors and the chemical factors is poorly understood and also requires elucidation.

4. Develop a reproducible scale for measuring odor intensity.

5. Develop a reproducible and meaningful method of characterizing or describing odors.

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MILWAUKEE WAS GREAT

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TOXICITY CHANGES OF STORED OIL REFINERY EFFLUENTS

Wm. R. Gould and Troy C. Dorris

The toxicity bio-assay is becoming an important tool for evaluating industrial effluents. Pollution laws generally require that effluents may not have a detrimental effect on aquatic life. The toxicity bio-assay is a means of evaluating the effects of effluents on aquatic life.

The collection, handling, and storage of effluent samples for testing presents problems to all technicians involved in toxicity bio-assay. Governmental enforcement agents and industrial waste control personnel alike are interested in the solution of problems which arise in use of the toxicity bio-assay.

This is a report in part of an extensive program of investigations of oil refinery effluents. Information was required by the industry on the effects of short periods of storage on toxicity. Sponsored research on a continuous-flow bio-assay of oil refinery effluents required information on the effects of long-term storage on the toxicity of oil refinery wastes.

Clemens and Summers (1) found that the toxicity of oil refinery wastes changed when stored at full strength in glass containers at room temperature. They found that the toxicity decreased with storage. However, experience in the studies reported here indicate that in some cases effluents do not change under storage.

Information is provided here on the effects of short- and long-term storage at room temperature on toxicity of oil refinery effluents of different degrees of toxicity. The study was conducted from July 1958 to October 1959.

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Characteristics of Effluents

Final effluents of four levels of toxicity were studied. Effluent 1 was toxic at a concentration of approximately 7 per cent by volume. This waste came from a catalytic poly-unit, a catalytic cracker, a platformer, a vis-breaker vacuum still, two crude distillation units, and the normal refinery operating processes. No information on the chemical composition of this effluent was available.

Effluent 2 was toxic at a concentration of approximately 18 per cent. This waste came from a crude unit, two coking units, a catalytic cracker, a catalytic reformer, a thermal reformer, and a compound house. Chemical characteristics are given in Table I.

Effluent 3 was toxic at a concentration of approximately 65 per cent. This waste was taken from a point part way along a series of holding ponds and contained waste from a crude unit, a thermal cracker, a catalytic cracker, an alkylation unit, and a vapor-recovery unit. Chemical characteristics are shown in Table II.

Effluent 4 was obtained from a holding pond. This waste came from desalters, atmospheric, vacuum-distillation, and topping crude units, thermal

TABLE I.—Chemical Characteristics of Effluent 2

Date (1958)	Sulfides (mg/l)	Phenols (mg/l)	NH_3 (mg/l)	pH	IOD (mg/l)	DO (mg/l)	Total Oils (mg/l)
Aug.	0.0	11.3	10.0	—	3.0	0.0	326

TABLE II.—Chemical Characteristics of Effluent 3

Date (1959)	Sulfides (mg/l)	Phenols (mg/l)	NH_3 (mg/l)	pH	COD (mg/l)
Aug.	0.0	0.5	23.0	9.0	190
Sept.	0.0	450.0	17.0	8.9	313
Oct.	0.0	2.5	25.0	8.9	189

cracking, catalytic reforming and polymerization, H.F. alkylation, lube-oil solvent treating, Perco, doctor treating, and dewaxing units. Table III gives the chemical characteristics.

Methods

Short-term storage of one to three days was required in the shipment of all oil refinery effluents to the laboratory for bio-assay tests. The need to store effluents for periods of approximately one month was anticipated for the continuous-flow bio-assay study. Bio-assay tests were run with each effluent at periods throughout the duration of storage to gain information on the effects of storage on the toxicity of oil refinery effluents.

All refinery effluents tested were stored in five-gallon polyethylene bottles which were filled to the top to exclude air and then stoppered or capped. To increase uniformity, the effluent samples were pumped into a large drum for mixing before being drained into the storage containers. The effluent samples were stored at a temperature of about 75°F.

All test animals used were fathead minnows (*Pimephales promelas*, Rafinesque) raised in ponds on the University campus. All fish were held in the laboratory for at least 10 days prior to use as suggested by Doudoroff *et al.* (2). During this time specimens that were diseased, injured, abnormal, undernourished, or showed breeding characteristics were discarded. All holding tanks were treated with Terramycin to prevent outbreak of a bacterial infection, "tail rot." The weight of all fish in a test container did not exceed one gram per liter. If, as happened a number of times, more than 10 per cent of the test animals became unfit for testing purposes, the entire series of tests was discontinued. A control of 10 to 20 fish taken at random from the stock population was placed in dilution water and observed simultaneously with each test.

Tap water was dechlorinated by aeration for at least 24 hr prior to use for dilution of the effluents. The water had been tested for a year before the tests and was found to be fairly constant in chemical content.

The test containers were polyethylene. Each test container was filled with 10 l of dilution water. Test concentrations were then made by removing the appropriate amounts of water and replacing them with effluent. In testing effluents 1 and 2, each concentration was replicated twice. In testing effluents 3 and 4, the number of replications was increased to four and the schedule of testing was modified to facilitate analysis of any changes that might occur. Five fish were used in each test container. Tests in the series 1 and 2 were maintained for a 96-hr test, but all tests in the series on effluents 3 and 4 were terminated after 48 hr. Tests were performed at 75°F. Hydrogen-ion concentration measurements were made with a line-operated pH meter. Dissolved oxygen concentrations were determined with a spectrophotometer.

The oxygen concentration was observed closely during the tests. Only test concentrations which remained above 1 mg/l dissolved oxygen were used in analysis of effluent toxic-

TABLE III.—Chemical Characteristics of Effluent 4

Date (1959)	Sulfides (mg/l)	Phenols (mg/l)	NH_3 (mg/l)	pH	COD (mg/l)
July	0.08	0.7	20.0	7.6	202
Aug.	0.06	1.6	18.0	7.2	177
Sept.	0.08	2.1	26.0	7.5	265

ities. This concentration was usually achieved by the high initial DO of the dilution water and the constant diffusion of oxygen from the air into the test medium. Test concentrations which approached the minimum allowable level of dissolved oxygen were treated by the addition of bubbles of pure oxygen (2) (3). Three test concentrations fell below the 1 mg/l minimum despite the added oxygen.

Measurement of Toxicity

Median tolerance limits (TL_m) are used in the analysis of the data. The values were determined by plotting data on mortality of more than 50 per cent and less than 50 per cent on semi-logarithmic paper, then using a straight-line interpolation to estimate the concentration of effluents that would cause a 50-per cent mortality.

Statistical Analysis

The derived median tolerance limits were treated statistically. The experiments were designed as randomized complete blocks. An analysis of variance table was computed. The calculated *F* (Fisher) value of treatments was compared with the tabulated *F* (Fisher) value. A probability statement was made for each effluent.

Results and Discussion

The initial 96-hr TL_m for effluent 1 was 7. No significant change in toxicity was found to occur in a 30-day test period. The pH did not change during this period.

Effluent 2 had an initial 96-hr TL_m of approximately 18. No significant change in toxicity took place in this effluent during a 30-day test period. No change in pH occurred during the 30-day test period.

Effluent 3 had an initial 48-hr median tolerance limit of approximately 65. There was no significant change in toxicity during the first four days of storage. Between the fourth and eighth days of storage the toxicity of this effluent decreased. No change in the pH of the effluent took place during the 32-day test period. An intensification in the color of the effluent was noticed at the beginning of the eighth day of storage.

No statistical information was obtainable from effluent 4 because it did not produce a sufficient number of tests in which 50 per cent or more of the fish were killed. Under such circumstances no measure of the median tolerance limit was obtainable and statistical analysis could not be applied properly to the test data. It was noted that a larger number of fish survived in the later tests of this effluent than in the earlier tests. The longer the effluent was stored the nearer the pH approached neutrality. From these observations it is suggested that this effluent decreased in toxicity during the period of storage.

Certain tentative conclusions may be drawn from the data presented here (Figure 1). When stored at room temperature without access to air, effluents of high initial toxicity (TL_m^{96} 7 and TL_m^{96} 18) show no change in toxicity over a storage period of 30 days. Effluents of intermediate toxicity (TL_m^{48} 65) undergo a change in toxicity after being stored a short time. It appears that effluents of very low toxicity (high TL_m) may also change during the period of storage.

Roberts (4) studied the populations of algae and bacteria in a series of oil-refinery effluent-holding ponds. He found few kinds of smaller organisms in large numbers in the earlier, high-toxicity portion of the pond series. In the lower-toxicity ponds later in the series he reported finding many kinds of larger organisms in smaller numbers.

The low toxicity effluents used in the present study were taken at points along series of effluent holding-ponds. It is believed that the low toxicity of these effluents was the result of biolog-

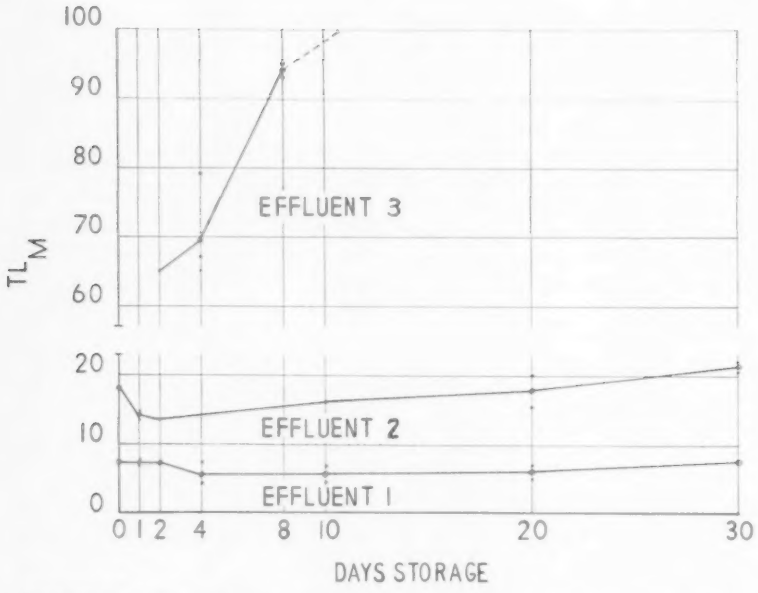

FIGURE 1.—The effects of storage on the toxicity of three oil refinery wastes. Solid line is mean value. Dashed line is extrapolated TL_m value.

ical action on effluents of initially high toxicity. In taking the samples the organisms in them were also taken. Undoubtedly some of these organisms continued to function under the storage conditions, thereby reducing the toxicity of the effluents throughout the storage period.

Effluents of high toxicity were taken from locations where they were subject to little biological action. The organisms present in these effluents apparently were not capable of producing significant changes in toxicity during the storage period.

Summary

1. A study was made to determine the effects of storage at room temperature on the toxicity of oil refinery effluents.

2. Oil refinery effluents of four levels of toxicity were studied and the results of bio-assay tests performed are presented.

3. Where possible a median tolerance limit was determined and treated statistically.

4. Effluent 1 (TL_m 7) did not change in toxicity during the 32-day storage period.

5. Effluent 2 (TL_m 18) did not show a significant change in toxicity during the 30-day storage period.

6. Effluent 3 (TL_m 65) decreased in toxicity during the fourth and eighth days of the 32-day storage period.

7. Effluent 4 did not kill a sufficient number of test animals to be treated statistically. There was evidence that the effluent decreased in toxicity during the storage period.

Acknowledgments

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tutes of Health, U. S. Public Health Service, and the Oklahoma Oil Refiners' Waste Control Council. This is Contribution No. 314, Department of Zoology, Oklahoma State University.

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8TH CONGRESS INTER-AMERICAN ASSOCIATION OF SANITARY ENGINEERING

For the first time the United States section of AIDIS will be host to the 1962 meeting of sanitary engineers and public administrators of the Americas. The meeting will be held in Washington, D. C., June 10–15, 1962, at the Departmental Auditorium, Constitution Avenue at 13th Street, in downtown Washington. For the past 14 years these meetings have been held in Central and South American countries.

A total attendance of 400 to 800 is expected and about half will be prominent sanitary engineers from the Latin American countries. Those attending will be men of considerable professional and official stature, many of ministerial and sub-ministerial level. Simultaneous translation service is anticipated to promote full understanding of the program by all.

A strong technical program is being planned and with the support which has been forthcoming from the manufacturers, the U. S. Public Health Service, and the International Cooperation Administration, an outstanding Congress will be assured.

The 5-day meeting will cover water resources planning, water supply technology, wastewater management, public utilities management, refuse, general sanitation, radioactive contaminants, air pollution, industrial hygiene, and national water supply planning.

An outstanding feature of the meeting will be exhibits by manufacturers from throughout the Americas. Anyone interested in exhibiting at the meeting is invited to write to John G. Stewart, Manager, Water and Sewage Works Manufacturers Association, 165 Broadway, New York 6.

All interested are invited to attend. The Willard Hotel, 12th and Pennsylvania Ave., N.W., will be headquarters.

For further information write to: Edmund G. Wagner, AIDIS Congress Chairman, Office of Public Health, International Cooperation Administration, Washington 25, D. C.

INDUSTRY AND POLLUTION ABATEMENT

Walter A. Lyon

Can industry grow in the face of an active pollution abatement program? This question not only demands an answer, but suggests a form of prophecy which is a dangerous pursuit.

Certainly industry has grown and is growing in areas where active pollution abatement programs exist.

Both the question and the answer tend to be misleading because they suggest that there is a direct relationship between pollution abatement and industrial growth. Certainly this was not true in the past. Industrial growth has been primarily due to the great wealth in human and natural resources. Water has certainly been an important resource, but in the past it has been generally abundant and therefore has not presented a problem.

One look at the list of principal water-using industries and utilities leaves no doubt that they represent an impressive segment of American economy. This list includes the chemical and allied products industries, food products, textiles, pulp and paper, the primary production of steel, copper, aluminum, petroleum and coal products, and the generation of electric power.

General Experience in Pennsylvania

In Pennsylvania control of industrial wastes was not included in clean streams legislation until 1937. Today approximately 1,300 industrial establishments are treating their wastes. This represents the major share of the water-using industrial establishments. This major effort in resource conservation on the part of Pennsylvania industry occurred during a period of industrial expansion and growth, and represents a fine record not merely in terms of dollars but also in terms of the engineering skill necessary to tangle with the complex problems of treating many types and varieties of industrial wastes.

Of course, good housekeeping and industrial waste treatment often result in the recovery of usable materials which are otherwise lost. In some cases these savings have been appreciable although they rarely absorb the entire cost of waste treatment.

There are a few companies which claim that to abate their pollution would result in business failure. A recent analysis of business failures, published by Dunn and Bradstreet, gives little evidence that regulatory activity by government, not to mention pollution abatement, is a factor at all. The March 1960 issue of Dunn's Review reports that during 1959 there were 2,465 business failures among manufacturing businesses. 92.8 per cent of these failures were reported as being caused by inexperience and incompetence by management. The remaining failures appear to be due to neglect, fraud, disaster, or unknown reasons.

It has been the experience in Pennsylvania that companies having financial difficulties for other reasons are often in difficulty with regard to their pollution abatement responsibilities too. The enforcement of pollution abatement laws may play a part in some business failures, but there is little evidence that this is a significant cause for failure.

On the other hand, it has been observed that a successful, well-managed

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The paper was presented at the 33rd Annual Meeting of the Water Pollution Control Federation in Philadelphia, Pa., Oct. 2–6, 1960.

business is more than eager to do a good job in treating its wastes. Management considers this a business obligation and a community responsibility. In some cases management has even gone further than this and has actually encouraged its employees not only to help abate pollution within the plant, but also to support pollution control efforts at all levels of government. Attractive literature and other means of communication have been used to encourage employees to participate in this job.

Future Prospects

If, then, pollution abatement efforts have not affected industrial growth, what can be expected of the future in this regard? If production, population, and water use predictions prove reliable (in the past they have been low) then the total national daily water use in 1980 will be about equal to the dependable fresh water supply. This does not necessarily represent a critical problem. There has been much progress in learning how to reuse water and even to use treated waste effluents. Water is reused many times along the length of a stream. Some companies located in water shortage areas, both in this country and abroad, have shown that they can exist on a fraction of the amount used by industry generally. For example, the Humble Oil Refinery at Baytown, Texas, recirculates its water 15 times. The Fontana Plant of Kaiser Steel conserves water by the same method and consumes only 1.7 per cent of the water per ton of steel used by the rest of the steel industry. European industry has shown that production can be increased in water-poor areas even while water consumption is lowered. Certainly the conservation of industrial water is only one solution to the pollution abatement problem. There are other problems which present themselves and to which there must be sensitive and responsive action. This country in the past few decades has undergone rapid social changes which have had an unbelievable impact on the use of water resources.

The general attitude toward work and leisure have changed markedly in the past several generations. Americans are becoming a leisure-oriented society. There not only are more leisure hours available, but people's lives are increasingly governed by leisure-time pursuits. The problem of recreation and leisure is even beginning to affect the selection of industrial sites. Population movement is affected by the recreation-oriented magnetism of California, Florida, and Arizona. There is no question now that pleasant living conditions tend not only to influence where Americans live and work, but they also have a fabulous impact on the entire economy.

Water and Recreation

The important point to remember in connection with this emphasis on leisure and recreation is that many of these activities are related to water. The fact that healthy streams help create a healthy society is very real to us in Pennsylvania. A map showing the 2,000 miles of Pennsylvania streams made acid and ruined by mine drainage reveals that these are also the depressed areas. On the other hand, the Erie Chamber of Commerce reported that Presque Isle State Park in Lake Erie accounted for $33 million in new business and investment in the immediate area of the park in 1960. This includes $10 million in direct purchases by park visitors, and such capital improvements as new motels, restaurants, etc. The attendance at Pennsylvania's state parks has tripled in seven years. Pennsylvania's recreation "industry" is valued in excess of $1 billion per year which would rank it eighth in relation to other industries and place it ahead of agriculture (on the farm) and mining. Last year 22 million people, nearly double the popu-

lation, used Pennsylvania state parks and nearly all of these uses were associated with water. The number of visitors at the Corps of Engineer's water resource projects in the United States increased from 16 million in 1950 to 107 million last year.

To most people proper recreational facilities mean water for boating, swimming, fishing, etc. These activities have brought large increases in business and industrial sales. The National Association of Engine and Boat Manufacturers reports that in 1958 more than $2 billion was spent in the United States for boat engines and associated expenditures. Last year more boats were purchased in California than new cars.

These changes can mean only one thing for pollution abatement in the years to come—the necessity for protecting all surface waters, not just some, for recreational purposes. This means that streams must have consistently clean water in them and that wastes must be treated before discharge rather than to have the situation where polluted waters are treated at the point of use.

Problems to Be Solved

In addition to the problem of gearing water resources to make them more attractive for further population and industrial growth, there are two other critical problems which must be met by industry and regulatory agencies working together. One of these is the problem of spills. The second is the need for research.

Spills

As industries and municipalities abate their pollution, accidental spills or intentional discharges occur from time to time on streams which are now relatively clean. These often cause fish kills. They are unexpected and unpredictable. To the water works operator who has adjusted his treatment to an improved quality, it may mean a sudden serious taste and odor problem, one which he has difficulty explaining to consumers.

Spills cannot be eliminated by writing regulations against them. They must be prevented by engineering measures and by management and employees who are convinced of the need to do something about this problem. An otherwise clean stream that is subjected to constant spills from industrial sources can raise as much havoc with water users as one that is chronically polluted.

Need for Research

The other problem is the need to spend much more money for research on the many new chemicals that are in use and passing through treatment works relatively unchanged. Waste treatment technology has so far not developed methods for treating them. Very little is known about some of these new chemicals, particularly about their toxicity to humans on a low-level, long-term basis or how to detect them in the low concentrations in which they often occur.

Summary

To sum up, there seems to be general agreement that active pollution abatement programs have in the past not impeded industrial growth, and in the future can only enhance economic strength because of the increasing importance of water resources to society. Increased free time is making society so leisure-oriented, and water is so much a part of leisure time pursuits that healthy industrial growth in this country is occurring in those sections where climate and water resources go hand in hand to provide an ideal recreational playground.

Recreational and leisure activities are essentially water-oriented and thus require a higher quality of water in the stream. Therefore, all waters must be protected for recreational, as well as domestic and industrial needs, in order to support nation-wide economic growth.

DEEDS AND DATA

"The only thing that never changes is the fact that nothing remains the same."—Anon.

Operational Data from the Annual Reports of Coral Gables, Fla., Gary, Ind., Jackson, Mich., Lexington, N. C., and Toledo, Ohio.

W. C. TIMS, *Superintendent, Division of Sanitary Sewers, Coral Gables, Fla.;* W. W. MATHEWS, *Superintendent, Gary Sanitary District, Gary, Ind.;* R. A. GREENE, *Superintendent, Sewage Treatment Plant, Jackson, Mich.;* JAMES G. STALLINGS, *Superintendent and Chemist, Sewage Treatment Plant, Lexington, N. C.;* and JAMES E. FROOK, *Commissioner, Division of Sewage Disposal, Toledo, Ohio.*

Operational Notes

The staff of the Coral Gables plant has a continuous operator training course in effect and the majority of employees are certified with the State Board of Health. Operators are allowed to attend Regional Short Schools and the State Short Course in Water and Sewage at Gainesville. Also the personnel are urged to take advantage of special courses given by the University of Miami. The expense of this additional training is shared by the City and the operators.

The grounds beautification program has been completed and an old surge tank has been converted into a repair and maintenance shop. This plant, located on the campus of the University of Miami, is maintained beautifully and complaints from nearby installations are few.

Equipment Additions

The Jackson, Mich., sewage plant has begun to increase its efficiency with additional equipment added during the past year. This equipment includes: a new screen building with a coarse bar screen, two barminutors, a grit tank and grit removal equipment, a Parshall flume, and meter. Improvements were also made to the collection system, particularly to the pumping stations.

Industrial Wastes

Sewer ordinances have reduced the industrial wastes introduced into the sanitary system at Jackson, but occasionally some are introduced inadvertently and operational changes are instituted to handle the unusual wastes until the flow returns to normal.

Operating Results

Table I shows the operating results from the five activated sludge plants listed in the heading of the article.

TABLE I.—Operating Results from Five Activated Sludge Plants

Treatment Plant	Operating Yr Ending	Est. Pop. Served (1000's)	Sewage Volume				Sewage Temp. (°F)			Sewage Strength (mg/l)				Efficiency of Treatment (%)						Grit Removed (cu ft/mil gal)
			Avg (mgd)	Max Day (mgd)	Min Day (mgd)	Per Cap (gpd)	Avg	Max	Min	Influent		Effluent		Primary Unit		Secondary Unit		Over-all		
										BOD	SS	BOD	SS	BOD	SS	BOD	SS	BOD	SS	
Coral Gables, Fla.	7/60	15.5	3.0	—	—	130	—	—	—	98	—	5	—	—	—	—	—	95	—	—
Gary, Ind.	12/61	170.0	30.1	—	—	177	60	—	—	217	509	12	14	62	72	86	96	94	97	5.1
Jackson, Mich.	6/60	50.0	10.3	15.9	4.6	207	60	72	50	116	192	8	16	20	13	87	87	94	92	0.8
Lexington, N. C.	12/60	15.7	1.0	1.7	0.5	64	67	—	—	318	184	18	43	30	54	70	54	94	77	—
Toledo, Ohio	12/60	—	53.5	104.3	32.6	—	62	71	53	171	265	32	99	—	—	—	—	81	59	—

Treatment Plant	Primary Sedimentation				Activated Sludge								
	Surface Overflow Rate (gpd/sq ft)	Raw Sludge			BOD Loading (lb/day/1,000 cu ft)	Air Use (cu ft/lb of BOD reduced)	Air Use (cu ft/gal of sewage)	Aeration Period (hr)	Sludge Return (%)	Mixed Liquor		Sludge Index	Cl_2 Dosage (mg/l)	Effluent Quality (MPN/ml)
		Volume (cu ft/mil gal of sewage)	Dry Solids (lb/mil gal of sewage)	Solids Conc. (%)						DO (mg/l)	SS (mg/l)			
Coral Gables, Fla.	—	—	—	—	19	784	—	—	—	—	—	—	8.1	173
Gary, Ind.	—	—	—	5.5	18.1	1,007	0.6	5.0	33	2.2	3,289	87	—	2,400
Jackson, Mich.	—	195	—	4.8	22.5	760	0.5	—	70	2.1	2,560	—	—	—
Lexington, N. C.	526	1,912	—	—	—	—	3.0	10.8	65	4.9	1,430	216	—	—
Toledo, Ohio	—	—	—	6.2	—	—	1.2	3.6	—	2.1	3,032	69	—	—

Treatment Plant	Sludge Digestion								Sludge Filtration				Operating Cost ($/mil gal)
	VS Loading (lb/day/1,000 cu ft)	VS Red. (%)	Temp. (°F)	Vol. Acids (mg/l)	Alk. (mg/l)	pH	Supernatant		Dry Yield (psf/hr)	$FeCl_3$ Fed (%)	CaO Fed (%)	TS in Cake (%)	
							Volume (cu ft/mil gal)	Solids Conc. (mg/l)					
Coral Gables, Fla.	—	55	—	—	—	—	—	—	—	15	62	—	—
Gary, Ind.	103	—	83*	—	—	—	—	—	—	—	—	—	26.76
Jackson, Mich.	98	50	85	—	—	—	—	1,150	—	—	—	—	60.62
Lexington, N. C.	—	—	—	—	—	6.8	—	—	—	—	—	—	105.28
Toledo, Ohio	—	—	77	—	—	—	—	—	—	—	—	—	33.74

Treatment Plant	Sludge Digestion — Gas				
	Produced (cu ft/day/cap)	Produced (cu ft/lb VS)	Used (%)	Heat Value (Btu/cu ft)	CO_2 (%)
Coral Gables, Fla.	0.7	—	—	—	—
Gary, Ind.	1.0	3.0	—	622	29
Jackson, Mich.	—	5.6	80	—	31
Lexington, N. C.	0.5	—	86	—	—
Toledo, Ohio	—	—	—	—	—

* Average of 5 primary digesters.

TIPS AND QUIPS

What Price Water—Salt or Fresh?

Despite the current great excitement about desalting the sea, the price of water delivered to your kitchen tap is still only a fraction of the cost of fresh water from the sea at the desalting plant. On the basis of a valid cost comparison, even the cheapest desalted sea water is on the order of twenty times as expensive as fully treated fresh water. Thus, according to the American Water Works Association, it will be some time before desalted sea water can be considered an economical alternative to fresh water as the sources of domestic water supply.

Actual desalting costs at the new Freeport, Tex., plant and other installations are reported to be approximately $1.00 per thousand gallons and up. There have been numerous claims of lower costs for unproved techniques and devices, but the $1.00 figure is generally accepted as the present goal for desalting. In the current enthusiasm about progress in the field of desalting, supporters have made much of the comparison between $1 per thousand-gallons of desalted water and fresh water at 20 to 70 cents per thousand gallons. The comparison, however, is the cost of operating a desalting plant, without taking into account depreciation of the equipment or delivery of the water or the administrative expenses involved in its sale, with the price of public supply at the tap at the highest unit rate.

The average cost of a thousand gallons of water to public water suppliers, as indicated by a recent survey of 497 utilities in the United States, was 12.3 cents, but this figure included not only the cost of treatment, but that of distribution, depreciation of plant equipment, and administrative costs. The cost of treatment for fresh water, including softening, approximates 5 cents per thousand gallons. And this is the figure that is comparable with the $1.00 cost of desalting.

As the Association sees the desalinization program, current research is of real importance as a means of preparing the nation for the future and, even more, as a means of benefiting some of the many water-short areas of the world. In the United States, however, total consumptive use of water at the present time is only about 10 per cent of the total fresh water supply economically available. Thus, except in most unusual circumstances, desalted water is of much less interest to public water suppliers than normal utility facilities.

Soap Sales *

Soap and synthetic detergent sales hit a new peak in 1960, according to the Association of American Soap and Glycerine Producers, Inc.

Fifty-eight manufacturers, representing a substantial portion of the industry, reported sales totaling 4.4 billions pounds valued at $1.1 billion. Sales were up 2.3 per cent in volume and 2.4 per cent in value from 1959, the previous record.

Sales of synthetics amounted to 3.3 billions pounds and $800.6 million, an increase of 3.3 per cent in pounds and 3.4 per cent in dollars over 1959.

Soap sales were about the same as 1959.

Simple

A $47,600 bond issue was passed by one vote. The only eligible voter of Sewer District No. 6 of the Quindaro Township, Kansas City, Kans., voted yes.

* From *California Water Pollution Control Association Newsletter*, Vol. 12 (Aug. 1961).

1961 Prize Winners Announced by ASCE

Recipients of the 1961 prizes, awards, and fellowships of the American Society of Civil Engineers have been announced following action by the ASCE Board of Direction. They include:

Norman Medal—Gold medals to Lorenz G. Straub and Alvin G. Anderson, University of Minnesota, Minneapolis, Minn., for technical paper, "Self-Aerated Flow in Open Channels."

J. James R. Croes Medal—A gold medal to George Winter, Cornell University, Ithaca, N. Y., for technical paper, "Lateral Bracing of Columns and Beams."

Thomas Fitch Rowland Prize—A cash award and certificate to Robert L. McNeill, Oakland, Calif., and H. Bolton Seed and Jacques de Guenin, University of California, Berkeley, for technical paper, "Clay Strength Increase Caused by Repeated Loading."

James Laurie Prize—A cash award and certificate to J. Barry Cooke, San Rafael, Calif., for technical paper, "Rockfill Dams: Wishon and Courtright Concrete Face Dams."

Collingwood Prize—A cash award and certificate to Sidney A. Guralnick, Illinois Institute of Technology, Chicago, for technical paper, "Strength of Reinforced Concrete Beams."

Arthur M. Wellington Prize—A cash award and certificate to T. William Lambe, Massachusetts Institute of Technology, Cambridge, Mass., for technical paper, "Compacted Clay: Engineering Behavior."

Construction Engineering Prize—A cash award and certificate to Gail Knight, Roscoe, N. Y., for technical paper, "Concreting the West Delaware Tunnel."

Rudolph Hering Medal—Bronze medals to A. L. Tholin and Clint J. Keifer, Chicago, for technical paper, "Hydrology of Urban Runoff."

Karl Emil Hilgard Hydraulic Prize—Cash award to Hunter Rouse and Tien To Siao, State University of Iowa, Iowa City, Iowa, and S. Nagaratnam, Chicago, for technical paper, "Turbulence Characteristics of the Hydraulic Jump."

Thomas A. Middlebrooks Award—Cash award to J. Barry Cooke, San Rafael, Calif., and I. C. Steele, San Francisco, Calif., for technical paper, "Salt Springs and Lower Bear River Concrete Face Dams."

Moisseiff Award—A bronze medal to John A. Blume, San Francisco, Calif., for technical paper, "Structural Dynamics in Earthquake-Resistant Design."

Rickey Medal—A bronze medal to Torald Mundal, San Francisco, Calif., for technical paper, "Rockfill Dams: Brownlee Sloping Core Dam."

J. C. Stevens Award—Books as prize to Daryl B. Simons, Colorado State University, and Everett V. Richardson, U. S. Geological Survey, Fort Collins, Colorado.

Theodore von Karman Medal—A bronze medal to R. D. Mindlin, Columbia University, New York City, in recognition of distinguished achievement in engineering mechanics.

Earnest E. Howard Award—A gold medal to Herschel H. Allen, Baltimore, Md., for contributions made to advancement of structural engineering.

Freeman Fellowship—A $3,000 grant to Jacques W. Delleur, Purdue University, Lafayette, Ind., for proposed study and research of secondary flows in non-circular conduits.

Research Fellowship—A $5,000 grant to Robert Brown Anderson, Carnegie Institute of Technology, Pittsburgh, Pa., for proposed original research in the field of brittle fractures.

JOURNAL of the WATER POLLUTION CONTROL FEDERATION (SEWAGE AND INDUSTRIAL WASTES until January 1960)

Official monthly publication of the Water Pollution Control Federation. An average of over 1,100 text pages annually affords coverage of all phases of research, design, construction, operation and management of works for the collection and treatment of sewage and industrial wastes as well as research and administration in stream pollution control and abatement. Major part of published material comes from technical programs presented at meetings of the Federation and its Member Associations. Edited by Ralph E. Fuhrman, Executive Secretary of the Federation. Single copies: U.S.A. and Canada, $1.25 each. Foreign, $1.50 each. Subscriptions: U.S.A. and Canada, $10.00 for one year. Foreign, $11.50 for one year.

TWENTY-YEAR INDEX TO SEWAGE WORKS JOURNAL

The first twenty volumes (115 numbers) of SEWAGE WORKS JOURNAL, covering the period 1928 through 1948, encompass an era of great progress in sewage and industrial wastes disposal. This index comprises three main sections, with listing by author, subject, and geographical location. Entries include the entire content of the JOURNAL—papers, editorials, committee reports, abstracts, Federation affairs, and fillers. Special attention has been given to the emphasis of key words and to cross-indexing. It is designed to lead the searcher to the reference quickly. 144 pages, bound in buckram. Price $3.00.

TEN-YEAR INDEX TO SEWAGE AND INDUSTRIAL WASTES

Volumes 21 through 30 of SEWAGE AND INDUSTRIAL WASTES (volume 21 was SEWAGE WORKS JOURNAL) covering the period 1949 through 1958. This index continues the pattern set by the earlier Twenty-Year Index in its three main sections of author, subject, and geographical listings. The index reflects special care in providing entries which are easy to locate and identify. Liberal use of multiple listings is included to facilitate ease and effectiveness to the user. 168 pages, in buckram, $4.00; and in heavy paper, $3.00.

GLOSSARY—WATER AND SEWAGE CONTROL ENGINEERING

Prepared by a joint committee representing WPCF (then FSIWA), ASCE, AWWA, and APHA. Contains 2,600 terms pertaining to nomenclature of hydrologic, hydraulic, and sewage works engineering fields. Paper cover edition $1.00.

Manual of Practice No. 1—SAFETY IN WASTEWATER WORKS

This first and most popular Federation "Safety Manual" has been revised and up-dated (1959) by the Federation Safety Committee. It includes safety information for operation and design of wastewater collection and treatment works. 64 pages. Single copies $1.50.

Manual of Practice No. 2—UTILIZATION OF SEWAGE SLUDGE AS FERTILIZER

Prepared by WPCF Sewage Works Practice Subcommittee on Sludge Uti-

lization for Fertilizer. An authoritative evaluation of the advantages and limitations of sewage sludge as a soil conditioner. Contains 45 tables, 251 references. 120 pages. Single copies $1.25.

Manual of Practice No. 5—AIR DIFFUSION IN SEWAGE WORKS

Prepared by the WPCF Committee on Air Diffusion, this Manual is a practical and useful guide to designers and operators of sewage works and industrial wastes treatment plants. The Manual traces the history of air diffusion as applied in sewage treatment, and outlines modern practice in design, installation, operation, and maintenance of diffuser systems and appurtenances. Bibliography of 61 references. 75 pages. Single copies $1.25.

Manual of Practice No. 6—UNITS OF EXPRESSION FOR WASTES AND WASTE TREATMENT

Prepared by the WPCF Subcommittee on Units of Expression, this Manual lists recommended units for quantities ordinarily encountered in wastes and waste treatment. It attempts to eliminate the heterogeneous units which have grown into sewage and industrial wastes practices. 8 pages. Single copies 50¢.

Manual of Practice No. 7—SEWER MAINTENANCE

Prepared by the Federation Committee on Sewer Maintenance. A guide to the proper practices for maintaining a municipal or industrial drainage system in serviceable condition. Examples of practice for systems of all sizes are included. About 70 pages. Well illustrated with nearly 15 pages of figures. Single copies $1.50.

Manual of Practice No. 8—SEWAGE TREATMENT PLANT DESIGN

Prepared by a Joint Committee of the Federation and ASCE. A detailed presentation based on information obtained from actual practice. 374 pages. Illustrated and documented with numerous references. $7.00 each.

Manual of Practice No. 9—DESIGN AND CONSTRUCTION OF SANITARY AND STORM SEWERS

Prepared by a Joint Committee of the Federation and ASCE. A presentation of the subject in full detail, based on the experience of many in this work. 283 pages. Fully illustrated and documented. $7.00 each.

Manual of Practice No. 10—UNIFORM SYSTEM OF ACCOUNTS FOR WASTEWATER UTILITIES

Prepared by the WPCF Committee on Sewage Works Finance. A 72-page revision of the 1949 accounting manual. Discusses origin, nature, and mechanics of accounting; the application of accounting to the administration of wastewater systems; presents the uniform system of accounts; develops a system of accounts for use in a medium-sized utility; and provides examples of the use of the uniform system. Single copies $3.00.

Manual of Practice No. 11—OPERATION OF WASTEWATER TREATMENT PLANTS

Prepared by the Federation Committee on Operation of Sewage Plants. Nearly 200 pages of comprehensive, well-illustrated material covering all phases of operation. Written for the operator, it should make life easier for

those now operating and should be indispensable in training new operators. The 22 chapters, each discussing a major topic of significance to the operator, were serialized in the Journal. Single copies $3.00.

BINDER

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4435 Wisconsin Avenue Washington 16, D. C.

NEWS AND NOTES

People and Events in the Wastewater Field

H. W. Streeter, of the U. S. Public Health Service and one of the pioneers in stream pollution studies, died recently.

Gordon M. Fair, Harvard University, has accepted the Chairmanship of the Committee on Sanitary Engineering and Environment of the Division of Medical Sciences, National Academy of Science, National Research Council. Abel Wolman, Johns Hopkins University, is the retiring Chairman.

Clinton L. Bogert has retired as an active member of the firm of Clinton Bogert Engineers. He will continue as a consultant to the firm.

A. L. Van Luven has been appointed Vice-Chairman of the newly-formed Quebec Water Purification Board. He formerly was with H. E. McKeen & Co. Ltd.

Stanley Lenox is heading the Divisional Product Planning and Development group, a new activity with the Permutit Company.

William L. Berk has joined Lakeside Engineering Corporation as Director of Product Development. He has been with Yeomans Brothers Co. the past six years.

Major C. Hagar has resigned as General Manager of the Sedalia (Mo.) Water Department to accept the newly created position of Director of Services for the City of Lee's Summit, Mo.

Charles E. Smith, Jr. has been appointed as process equipment regional sales manager by Chain Belt Co. He will remain in the Philadelphia office.

B-I-F Industries is now a division of the New York Air Brake Company.

Fenton H. Dobb, Supervisor of Industrial Wastes Engineering for the City of Cincinnati, Ohio, is retiring November 1.

R. D. Wood Company has moved its general offices to Florence, N. J.

Fred H. Puckhaber is now associated with Black and Veatch of Kansas City, Mo. He will be located in Dallas, Tex.

Frank A. Butrico is heading the Office of Resource Development, newly established within the Bureau of State Services of the U. S. Public Health Service.

William R. McGarry is the new President of United States Concrete Pipe Co., a subsidiary of Pittsburgh Coke and Chemical Co.

Lloyd D. Knapp, Commissioner of Public Works of Milwaukee, has been nominated as a Regional Director of the American Public Works Association.

David R. Miller has left the position of special sanitary engineer for the Ninth Naval District to form the firm of David R. Miller and Associates. Emery Ikan, formerly of Yeomans Brothers Co., is associated with the new firm.

Edwin J. Barton and **Kenneth R. Brown** have left O'Brien & Gere to become partners in the new firm of Barton, Brown, Clyde, & Loguidice in Syracuse, N. Y.

Morton I. Goldman has joined Nuclear Utilities Services, Inc., of Washington, D. C. He leaves the U. S. Public Health Service for this new post.

Arnold H. Haverlee, former Technical Director of Cloroben Chemical Co., has been appointed Technical Director of the Director of the Division of Pollution Control Chemicals of Fine Organics, Inc.

Alfred P. Bernhart, President of the engineering firm of Alfred P. Bernhart Associates Ltd., Toronto, Ont., has received an appointment as Assistant Professor of Civil Engineering at the University of Toronto.

Robert E. Steimke is the new Director of the Experiment Station at the Georgia Institute of Technology.

Harold E. Babbitt, Professor Emeritus of Sanitary Engineering at the University of Illinois, is spending the 1961–62 academic year in India as part of a team of American experts who will be assisting to Indians in an improved educational program. The project is sponsored by ICA and the University of Wisconsin. Professor Babbitt will be located at the University of Roorkee.

Ray L. Derby, Principal Sanitary Engineer in the Los Angeles Department of Water and Power; and **Fred Merryfield**, Partner, **Cornell, Howland, Hayes & Merryfield**, recently were elected to honorary membership in the American Water Works Association.

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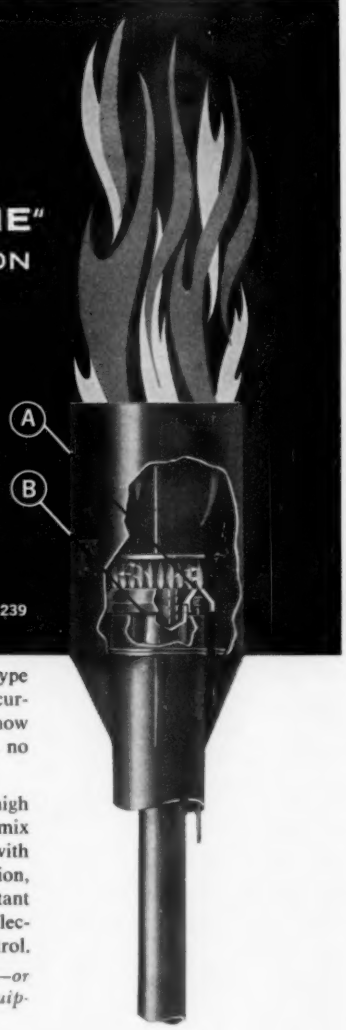

FIG. NO. 239

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WATER POLLUTION CONTROL PRODUCT GUIDE

This list of products and services is offered as an information aid. The list was derived by solicitation from those firms listed. The JOURNAL will make every effort to keep this list current with the help of Associate Members and advertisers. All Associate Members and all advertisers for the past year are included. Many of the services and products are advertised in this issue. For an alphabetical listing see Index to Advertisers in back of JOURNAL. Write to the Federation office for complete address and representative.

Aerators (*also see* Diffusers, Air)
Alpha Ltd. (Switzerland)
American Well Works
Chicago Pump Co.
Dorr-Oliver Inc.
Eimco Corp.
Graver Water Conditioning Co.
Infilco Inc.
Link-Belt Co.
Pacific Flush Tank Co.
Permutit Co., Div. of Pfaudler Permutit Inc.
Smith & Loveless
Walker Process Equipment Inc.
Wemco Div., Western Machinery Co.
Yeomans Brothers Co.
Zimmer & Francescon

Agitators
Link-Belt Co.

Air Cleaning Equipment
Westinghouse Electric Corp.

Air Compressors (*also see* Blowers, Compressors, and Fans)
Chicago Pump Co.
Fairbanks, Morse & Co.
Komline-Sanderson Engr. Corp.
Worthington Corp.
Yeomans Brothers Co.

Air Diffusers (*see* Diffusers, Air)

Asbestos Cement Pipe Products
Filtration Equipment Corp.
Industrial Materials Co.
Johns-Manville Sales Corp.
Keasbey & Mattison Co.

Ash Handling Equipment
Link-Belt Co.

Bearings
Link-Belt Co.

Bins, Storage (*see* Tanks)

Biologists (*see* Professional Services, elsewhere in this issue)

Blowers (*also see* Air Compressors, Compressors, and Fans)
Chicago Pump Co.
Roots-Connersville Blower, Div. of Dresser Industries Inc.
Sutorbilt Corp.
Yeomans Brothers Co.
Zimmer & Francescon

Boilers
Combustion Engineering, Inc.

Building Maintenance Equipment and Supplies
Homestead Valve Mfg. Co.

Cast Iron Pipe Products
American Cast Iron Pipe Co.
Cast Iron Pipe Research Assn.
Industrial Materials Co.
U. S. Pipe & Foundry Co.
R. D. Wood Co.

Cement (*see* Concrete)

Centrifuging Equipment
Bird Machine Co.
Permutit Co., Div. of Pfaudler Permutit Inc.

Chains
Chain Belt Co.
Link-Belt Co.

Chemical Feed Equipment
Builders-Providence Div., B-I-F Industries
Capital Controls Co., Inc.
Eimco Corp.
Fischer & Porter Co.
Graver Water Conditioning Co.
Infilco Inc.
Jeffrey Mfg. Co.
Komline-Sanderson Engr. Corp.
Link-Belt Co.
Omega Div., B-I-F Industries
Permutit Co., Div. of Pfaudler Permutit Inc.
Proportioneers Div., B-I-F Industries
Wallace & Tiernan Inc.

Chemicals
Brooks Chemicals, Inc.
Dow Chemical Co.
Fisher Scientific Co.
General Chemical Div., Allied Chemical Corp.
Glenn Chemical Co.
Hach Co.
Tennessee Corp.

Chemists (*see* Professional Services, elsewhere in this issue)

Chlorination Equipment
Builders-Providence Div., B-I-F Industries
Capital Controls Co., Inc.
Fischer & Porter Co.
Graver Water Conditioning Co.
Wallace & Tiernan Inc.
Zimmer & Francescon

Clarifier Equipment (*also see* Sedimentation Equipment)
Alpha Ltd. (Switzerland)
American Well Works
Ralph B. Carter Co.
Chain Belt Co.
Chicago Pump Co.
Dorr-Oliver Inc.
Eimco Corp.
Graver Water Conditioning Co.
Hardinge Co., Inc.
Infilco Inc.
Jeffrey Mfg. Co.
Komline-Sanderson Engr. Corp.
Lakeside Engineering Corp.
Link-Belt Co.
Permutit Co., Div. of Pfaudler Permutit Co.
Walker Process Equipment Inc.
Yeomans Brothers Co.
Zimmer & Francescon

Clay Pipe Products
W. S. Dickey Clay Mfg. Co.
Industrial Materials Co.
National Clay Pipe Mfrs., Inc.
Robinson Clay Product Co.

Coatings and Linings (Pipe and Tank)
Amercoat Corp.
Centriline Corp.
Inertol Co., Inc.
Koppers Co., Inc.
Lock Joint Pipe Co.
National Water Main Cleaning Co.
Perry-Austen Mfg. Co.
Stebbins Engr. & Mfg. Co.

Comminutors (*also see* Shredders and Grinders)
Alpha Ltd. (Switzerland)
American Well Works
Chicago Pump Co.
Dorr-Oliver Inc.
Gruendler Crusher & Pulverizer Co.
Infilco Inc.
Jeffrey Mfg. Co.
Smith & Loveless
Walker Process Equipment Inc.
Worthington Corp.

Compressors
Chicago Pump Co.
Fairbanks, Morse & Co.
Ingersoll-Rand Co.
Komline-Sanderson Engr. Corp.
Roots-Connersville Blower, Div. of Dresser Industries Inc.
Worthington Corp.
Yeomans Brothers Co.

Computers
Minneapolis-Honeywell Regulator Co., Brown Instruments Div.

Concentrators (*see* Sludge Concentrators)

Concrete
Portland Cement Assn.

Concrete Pipe Products
American Concrete Pressure Pipe Assn.
American-Marietta Co.
Industrial Materials Co.
Lock Joint Pipe Co.
Price Brothers Co.

Construction Equipment
Chain Belt Co.
Eimco Corp.
Worthington Corp.

PROCEEDINGS OF MEMBER ASSOCIATIONS

NEW YORK WATER POLLUTION CONTROL ASSOCIATION

The 33rd Annual Meeting of the New York Water Pollution Control Association was held at the Park Sheraton Hotel, New York City, Jan. 18–20, 1961. A total of 290 members and guests was registered.

The annual dinner meeting of the Executive Committee was held on Wednesday, Jan. 18. Following reports of the Executive Secretary and Treasurer, there were remarks by the guests from the Federation. President Ray E. Lawrence discussed the Federation's participation in the recent Surgeon General's Conference on Pollution Abatement. Executive Secretary Ralph E. Fuhrman discussed the name change, membership, the new Federation exhibit booth, and the action on the invitation to hold the 1967 Federation convention in New York City. Philip A. Ridgely, with the Federation's Washington office, spoke on its public relations plans, the purpose of the new exhibit, and the need for public relations by each Member Association on the local level.

The Annual Awards Luncheon was attended by 181 members and guests. Mr. Lawrence presented the Bedell Award to C. E. Irving, Superintendent, Bureau of Sewage Treatment, Schenectady; and the Hatfield Award to F. J. Cramer, Superintendent,

(*Continued on page 587a*)

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Minneapolis-Honeywell Regulator Co., Brown Instruments Div.
Ohmart Corp.
Penn Instruments Div., Penn Meter Co.
Permutit Co., Div. of Pfaudler Permutit Co. Inc.
Rockwell Mfg. Co.
Wallace & Tiernan Inc.
Westinghouse Electric Corp.
Worthington Corp.

Conveyors
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Chain Belt Co.
Chicago Pump Co.
Jeffrey Mfg. Co.
Link-Belt Co.
Stuart Corp.

Corrosion Protection
Amercoat Corp.
Chicago Pump Co.
Inertol Co., Inc.
Johns-Manville Sales Corp.
Koppers Co., Inc.
Lock Joint Pipe Co.
Perry-Austen Mfg. Co.
A. O. Smith Corp.
Stebbins Engr. & Mfg. Co.
Wallace & Tiernan Inc.

Couplings
Link-Belt Co.

Diffusers, Air (*also see* Aerators)
Alpha Ltd. (Switzerland)
American Well Works
Carborundum Co.
Chicago Pump Co.
Dorr-Oliver Inc.
Eimco Corp.
Infilco Inc.
Lakeside Engineering Corp.
Link-Belt Co.
Pacific Flush Tank Co.
Walker Process Equipment Inc.
Wemco Div., Western Machinery Co.
Zimmer & Francescon

Diffusers, Gas (*also see* Aerators)
American Well Works
Carborundum Co.
Chicago Pump Co.
Eimco Corp.
Infilco Inc.
Walker Process Equipment Inc.
Yeomans Brothers Co.

Digestion Tank Equipment
Alpha Ltd. (Switzerland)
American Well Works
Ralph B. Carter Co.
Chicago Pump Co.
Dorr-Oliver Inc.
Eimco Corp.
Gorman-Rupp Co.
Hardinge Co., Inc.
Infilco Inc.
Jeffrey Mfg. Co.
Lakeside Engineering Corp.
Link-Belt Co.
Pacific Flush Tank Co.
A. O. Smith Corp.
Smith & Loveless
Varec, Inc.
Walker Process Equipment Inc
Yeomans Brothers Co.
Zimmer & Francescon

Distributors, Rotary
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Eimco Corp.
Infilco Inc.
Lakeside Engineering Corp.
Link-Belt Co.
Pacific Flush Tank Co.
Smith & Loveless
Walker Process Equipment Inc.
Yeomans Brothers Co.
Zimmer & Francescon

Dryers
Alpha Ltd. (Switzerland)
Combustion Engineering, Inc.
Eimco Corp.
Hardinge Co., Inc.
Komline-Sanderson Engr. Corp.
Link-Belt Co.
Nichols Engr. & Research Corp.
Stuart Corp.

Ejectors
Komline-Sanderson Engr. Corp.
Smith & Loveless
Tex-Vit Mfg. Co.
Yeomans Brothers Co.

Engineers (*see* Professional Services, elsewhere in this issue)

Engines (Sludge Gas and Petroleum Fuels)
Fairbanks, Morse & Co.
Waukesha Motor Co.
Worthington Corp.

Fans (*also see* Air Compressors, Blowers, and Compressors)
Chicago Pump Co.
Lakeside Engineering Corp.
Westinghouse Electric Corp.

Filter Equipment, Trickling
Alpha Ltd. (Switzerland)
American Well Works
Ralph B. Carter Co.
W. S. Dickey Clay Mfg. Co.
Dorr-Oliver Inc.
Dow Chemical Co.
Eimco Corp.
Filtration Equipment Corp.
Industrial Materials Co.
Infilco Inc.
Keasbey & Mattison Co.
Komline-Sanderson Engr. Corp.
Lakeside Engineering Corp.
Nichols Engr. & Research Corp.
Pacific Flush Tank Co.
Smith & Loveless
Trickling Filter Floor Inst.
Walker Process Equipment Inc.
Yeomans Brothers Co.
Zimmer & Francescon

Filter Materials
Carborundum Co.
Filtration Equipment Corp.
Glenn Chemical Co.
Graver Water Conditioning Co.
Industrial Materials Co.
Johns-Manville Sales Corp.

Filters, Diatomaceous Earth
Graver Water Conditioning Co.
Yeomans Brothers Co.

Filters, Vacuum (*also see* Vacuum Filters)
Bird Machine Co.
Dorr-Oliver Inc.
Eimco Corp.
Proportioneers Div., B-I-F Industries

Flocculating Equipment
Alpha Ltd. (Switzerland)
American Well Works
Ralph B. Carter Co.
Chain Belt Co.
Dorr-Oliver Inc.
Eimco Corp.
Graver Water Conditioning Co.
Hardinge Co., Inc.
Infilco Inc.
Jeffrey Mfg. Co.
Lakeside Engineering Corp.
Link-Belt Co.
Permutit Co., Div. of Pfaudler Permutit Inc.
Stuart Corp.
Walker Process Equipment Inc.
Zimmer & Francescon

Flotation Equipment
Chain Belt Co.
Dorr-Oliver Inc.
Eimco Corp.
Graver Water Conditioning Co.
Komline-Sanderson Engr. Corp.
Yeomans Brothers Co.

Flow Measurement
Filtration Equipment Corp.
F. B. Leopold Co., Inc.
Penn Instruments Div., Penn Meter Co.

Gas Control Equipment
Alpha Ltd. (Switzerland)
Ralph B. Carter Co.
Chicago Pump Co.
Dorr-Oliver Inc.
Eimco Corp.
Foxboro Co.
Homestead Valve Mfg. Co.
Pacific Flush Tank Co.
Penn Instruments Div., Penn Meter Co.
Rockwell Mfg. Co.
Varec, Inc.
Walker Process Equipment Inc.
Zimmer & Francescon

Gas Diffusers (*see* Diffusers, Gas)

Gas Holders, Boilers, and Appurtenances
Ralph B. Carter Co.
Chicago Pump Co.
Dorr-Oliver Inc.
Eimco Corp.
Johns-Manville Sales Corp.
Walker Process Equipment Inc.

Gaskets
Johns-Manville Sales Corp.
Keasbey & Mattison Co.

Gates
Armco Drainage & Metal Products, Inc.
Filtration Equipment Corp.
Industrial Materials Co.
Snow Gates & Valves, Inc.

Generators
Fairbanks, Morse & Co.
General Electric Co.
Westinghouse Electric Corp.
Worthington Corp.

Grease Control Materials
Rhodia Inc.

Grinders (*also see* Shredders and Grinders)
Alpha Ltd. (Switzerland)
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Yeomans Brothers Co.

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Walker Process Equipment Inc.
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Water and Sewage Treatment Plant, Rochester. The guest speaker, Myron H. Bengson, Applications Physicist, General Electric Co., Radnor, Pa., spoke on, "Waste Disposal in a Space Vehicle."

Papers presented were:

"Plating Waste Treatment—No Longer a Necessary Evil," by Lawrence A. Greenberg, Systems Application Engineer, Fischer and Porter Co., Warminster, Pa.

"Effect of Laundry Wastes on Ground Water Supply," by Barry Andres, Sanitary Engineer, C. W. Lauman Co., Hicksville; and John M. Flynn, Associate Public Health Engineer, Suffolk County Health Dept., Riverhead.

"Activated Sludge Treatment of Kraft Waste at the Upper Potomac River Commission Plant," by Francis P. Coughlan, Associate, Hazen and Sawyer, New York City.

"Industrial Wastes Treatment Aids in Pollution Abatement Control," by Rolland W. Simpson, Chief Sanitary Engineer, Gilbert Associates, Inc., Reading, Pa.

Panel discussion on: "Public Relations for Sewerage and Waste Water Treatment," with Hartley Sandt, Johns Manville Sales Corp., Glen Cove, as moderator. The following took part in the discussion: Kermit Hill, Public Relations Counsel, Astro Agency, Inc., Rochester; Dean Kearsh, Account Executive, J. Walter Thompson Advertising Agency, New York City; Ernest Neufeld, Executive Director, Borough of Queens, New York City; Robert D. Hennigan, Chief, Water Pollution Control Section, State Department of Health, Albany; and Kenneth S. Watson, Consultant, Water Management and Waste Control, General Electric Co., Schenectady.

"Pollution Abatement Program of the City of Rochester," by John L. Lewis, Commissioner of Public Works,

(*Continued on page 592a*)

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One of eight Ohmart Sludge Density Gages at Pittsburgh's Allegheny Cty. Disposal Plant

- Pump more solids—less liquid.
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American Pipe & Construction Co.
Armco Drainage & Metal Products, Inc.
Keasbey & Mattison Co.
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Plastic Pipe Products
Amercoat Corp.
Evanite Plastic Co.
Keasbey & Mattison Co.
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Publications
American City Magazine
Engineering News-Record
Liverpool University Press (England)
Public Works Magazine
Wastes Engineering Magazine
Water & Sewage Works

Pump Controls
Builders-Providence Div., B-I-F Industries
Chicago Pump Co.
Fischer & Porter Co.
Foxboro Co.
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Personnel Wanted

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Water pollution control engineer A, or water pollution control specialist for work with industrial wastes. Salary range: engineer, $5880–$7344; specialist, $5640–$7032. Qualification standards: engineer, B.S. degree in chemistry or chemical engineering, preferably with options in sanitary engineering and at least 1 yr sanitary engineering experience; specialist, B.S. degree in chemistry or the biological sciences, and 1 yr experience in pollution control work. Apply to Virginia State Water Control Bd., P. O. Box 5285, Richmond 20, Va.

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Sutorbilt Corp.

Pumps, Grit
Nagle Pumps, Inc.

Pumps, Sewage
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Ralph B. Carter Co.
Chain Belt Co.
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Fairbanks, Morse & Co.
Gorman-Rupp Co.
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Rochester; and Newell L. Nussbaumer, Consulting Engineer, Buffalo.

"Organic Pollution and Self Purification of New York Harbor," by John S. McCabe, Project Engineer, Lockwood, Kessler and Bartlett, Syosset; and Donald J. O'Connor, Associate Professor of Civil Engineering, Manhattan College, Riverdale.

"Design Features of the Hoboken, New Jersey Sewage Works," by John G. Albertson, Partner, Bowe, Albertson and Associates, New York City.

"Interstate Elutriation of Digested Sludge at Owls Head Plant," by A. H. Chasick, Engineer in Charge, and R. T. Dewling, Assistant Civil Engineer, both of the Sewage Treatment Section, Bureau of Sewage Disposal, Department of Public Works, New York City.

These are the officers for 1961:

President: Guy Griffin, Chappaqua.
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4435 Wisconsin Ave., Washington 16, D. C.

INDIANA WATER POLLUTION CONTROL ASSOCIATION

The 24th Annual Conference of the Indiana Sewage and Industrial Wastes Association was held at the Hotel Washington, Indianapolis, Ind., Nov. 16–17, 1960. Total registration was 186, plus approximately 20 ladies. The members present voted to change the name of the association to the Indiana Water Pollution Control Association.

Harry E. Schlenz, WPCF Vice-President, represented the Federation at the meeting. A speaker at both the banquet and the business meeting, he complimented the Indiana Association on its membership increase and on winning the membership award of the Federation. Mr. Schlenz presented the Bedell Award to B. A. Poole, Director, Bureau of Environmental Sanitation, Indiana State Board of Health and Executive Secretary, Indiana Stream Pollution Control Board; and the Hatfield Award to W. W. Mathews, Superintendent, Gary Sanitary District, Gary.

Officers for 1960–61 are:

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First Vice-President: Dwight O. Bender, Indianapolis.
Second Vice-President: Frank D. Wraight, Indianapolis.
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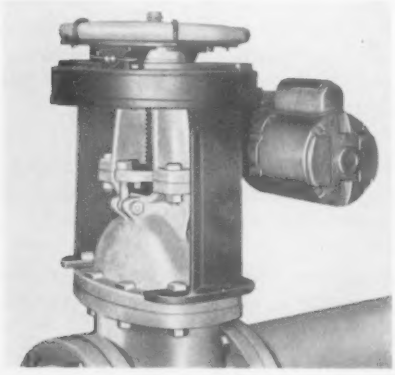

Flexible Flanged Coupling Adapters—Ease of installation of valves, meters, etc., by use of this new product, is claimed by the manufacturer. Particulars are given in catalog No. 1255. Smith-Blair, Inc., 535 Railroad Ave., South San Francisco, Calif.

Solids Flow Meter—A new illustrated specification sheet describing the operation of a new solids flow meter is available from the Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland 10, Ohio.

Turbidity Transmitter—An instrument that measures the percentage of solids in a liquid and transmits this measurement to recording equipment is now available. The unit includes a flow chamber, a light source, and a Bailey bolometer. Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland, Ohio.

Car Desk—A new portable car desk, clip board when detached, is designed to fit all cars or trucks. It has a 12- by 20-in. writing surface, and comes in either masonite or plastic. Mishek Supply Co., Waseca, Minn.

WPCF publications

Safety in Wastewater Works

Information on hazards, accident statistics, rescue methods, safe practices, and equipment. *56 pages. $0.75 to members; $1.50 to others. Item MOP-1.**

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An authoritative evaluation of advantages and limitations of sludge as a soil conditioner. *120 pages. $0.75 to members; $1.25 to others. Item MOP-2.**

Air Diffusion in Sewage Works

History and modern practice in design, installation, operation, and maintenance of diffuser systems and appurtenances. *75 pages. $1.00 to members; $1.25 to others. Item MOP-5.**

Units of Expression for Wastes and Waste Treatment

Lists of recommended units for quantities ordinarily encountered in wastes and waste treatment. *8 pages. $0.25 to members; $0.50 to others. Item MOP-6.**

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A completely revised, 72-page manual of the 1949 accounting manual. Provides the entire accounting procedure for a utility. *$2.00 for members; $3.00 for others. MOP-10.**

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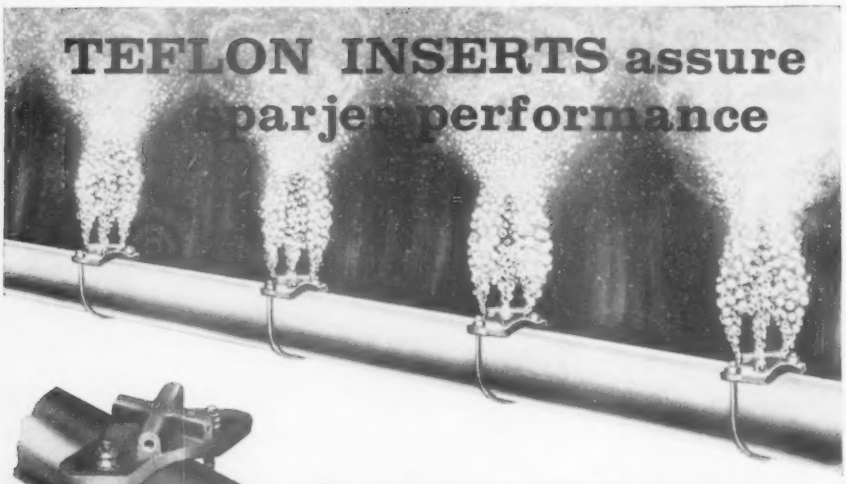

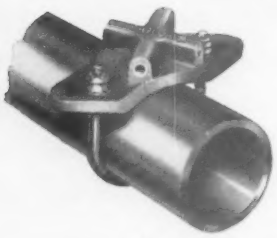

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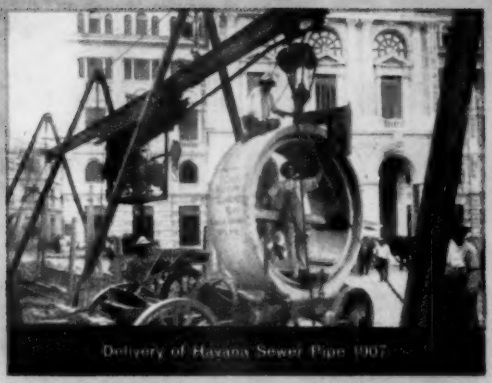

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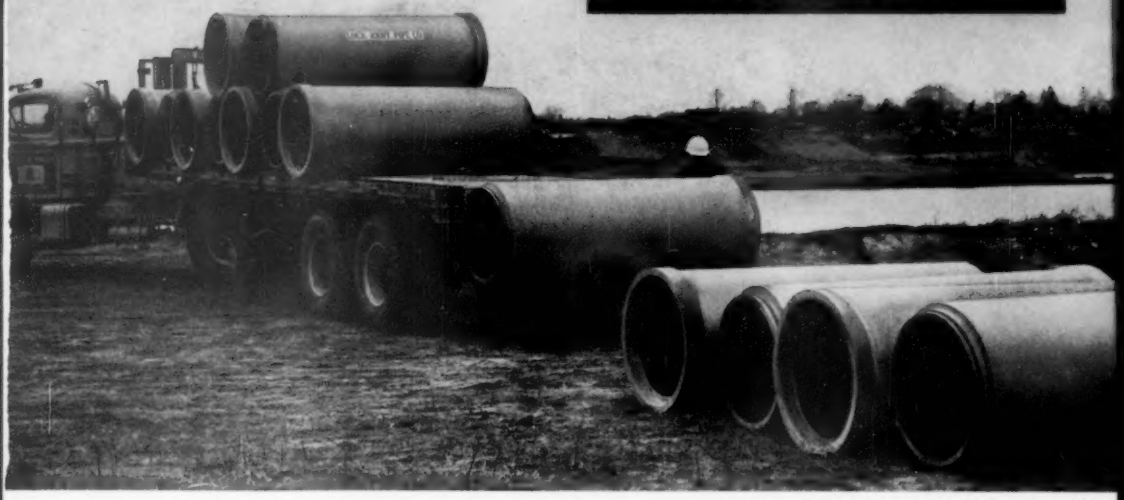

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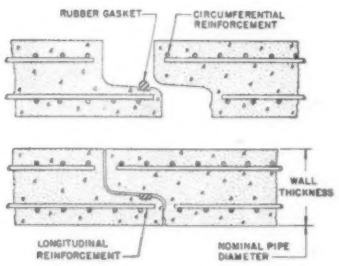

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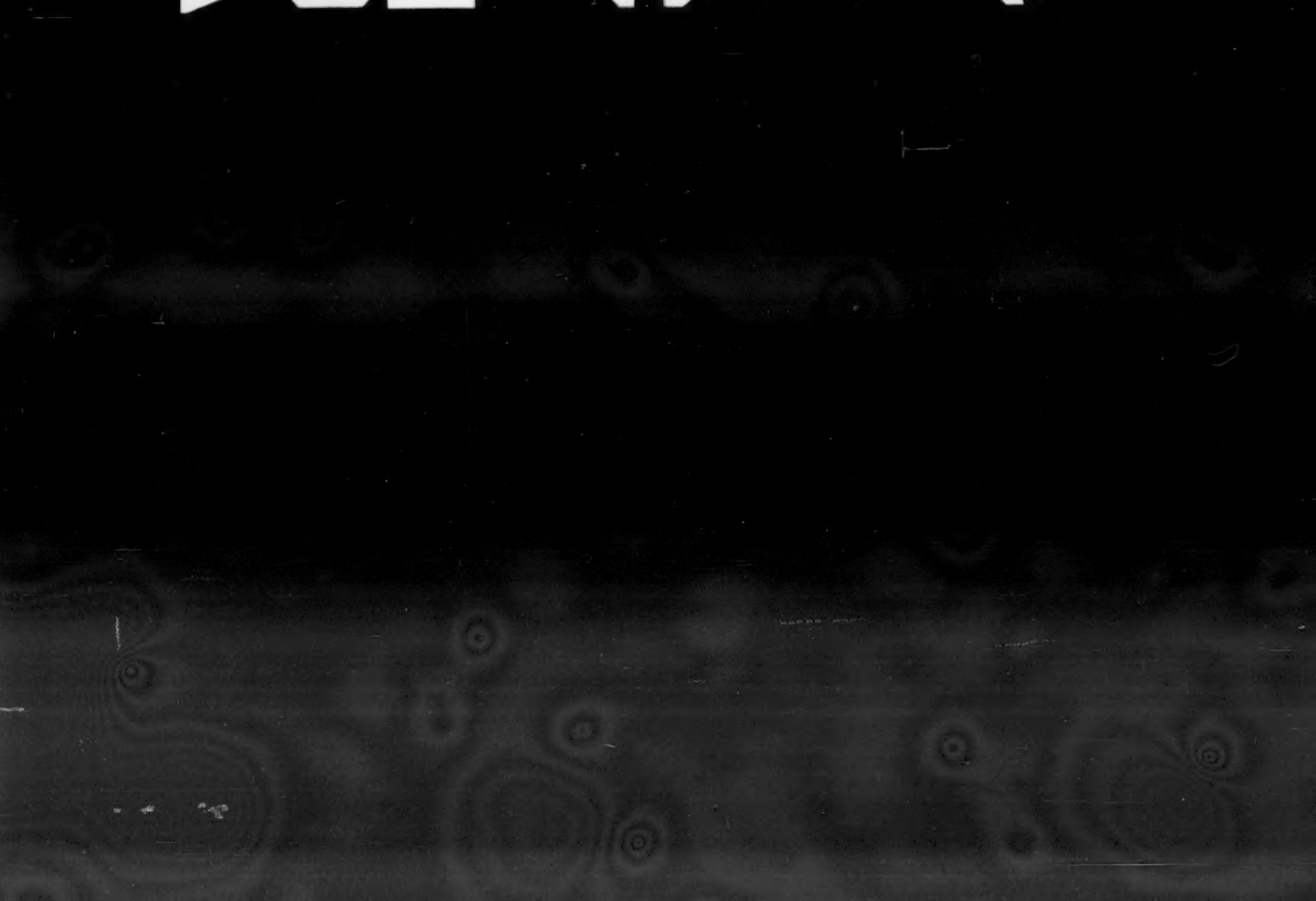
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